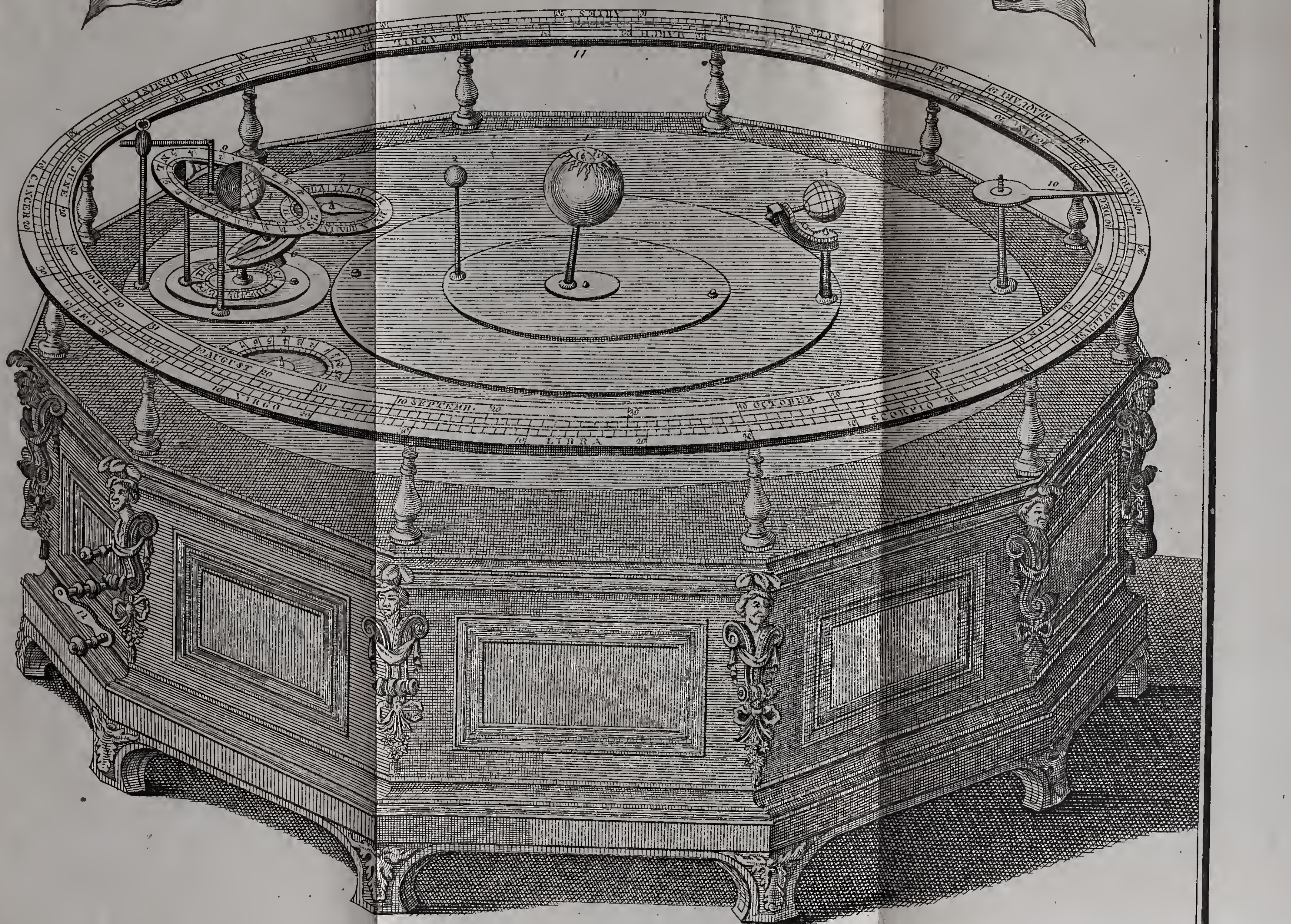

NIL SISTERE CONTRA

The ORRERY, made by *JAMES FERGUSON*.



N.º 1 The Sun, 2 Mercury, 3 Venus, 4 The Earth, 5 The Moon, 6 The Sydereal Dial plate, 7 The Hour Circle, 8 ye Circle for ye Moon's Ecl. 9 the Moon's Orbit, 10 ye Pointer, shewing the Sun's Place & Day of the Month, 11 The Ecliptic, 12 The Handle for turning ye whole machine

J. Ferguson inv. et deline. G. Child Sculp.

ASTRONOMY

EXPLAINED UPON

SIR ISAAC NEWTON's PRINCIPLES,

And made easy to those who have not studied

MATHEMATICS.

TO WHICH ARE ADDED,

A PLAIN METHOD

OF FINDING THE

DISTANCES of all the PLANETS from the SUN,

BY THE

TRANSIT of VENUS over the SUN's DISC, in the Year 1761.

An Account of Mr. HORROX's Observation of the TRANSIT of VENUS in the Year 1639:

AND,

Of the DISTANCES of all the PLANETS from the SUN, as deduced from OBSERVATIONS of the TRANSIT in the Year 1761.

By JAMES FERGUSON, F. R. S.

HEB. xi. 3. *The Worlds were framed by the Word of* GOD.
JOB, xxvi. 7. *He hangeth the Earth upon nothing.*
——— 13. *By his Spirit he hath garnished the Heavens.*

THE NINTH EDITION.

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M DCC XCIV.

TO

THE RIGHT HONOURABLE

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VISCOUNT PARKER of EWELME in OXFORDSHIRE,

AND

BARON of MACCLESFIELD in CHESHIRE,

PRESIDENT OF THE ROYAL SOCIETY OF LONDON,

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OF THE

IMPERIAL ACADEMY OF SCIENCES AT PETERSBURGH,

AND ONE OF THE

TRUSTEES OF THE BRITISH MUSEUM;

DISTINGUISHED

BY HIS GENEROUS ZEAL FOR PROMOTING

EVERY BRANCH OF USEFUL KNOWLEDGE;

THIS

TREATISE of ASTRONOMY

IS INSCRIBED,

WITH THE MOST PROFOUND RESPECT,

BY HIS LORDSHIP's

MOST OBLIGED AND

MOST HUMBLE SERVANT,

JAMES FERGUSON.

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ASTRONOMY

EXPLAINED UPON

SIR ISAAC NEWTON's PRINCIPLES.

CHAP. I.

Of Aſtronomy in general.

1. OF all the ſciences cultivated by mankind, Aſtronomy is acknowledged to be, and undoubtedly is, the moſt ſublime, the moſt intereſting, and the moſt uſeful. For, by knowledge derived from this ſcience, not only the bulk of the earth is diſcovered, the ſituation and extent of the countries and kingdoms upon it aſcertained, trade and commerce carried on to the remoteſt part of the world, and the various products of ſeveral countries diſtributed for the health, comfort, and conveniency of its inhabitants; but our very faculties are enlarged with the grandeur of the ideas it conveys, our minds exalted above the low contracted prejudices of the vulgar, and our underſtandings clearly convinced, and affected with the conviction of the exiſtence, wiſdom, power, goodneſs, immutability, and ſuperintendency of the SUPREME BEING! So that without an hyperbole, The general uſe of Aſtronomy.

"*An undevout Aſtronomer is mad*.*"

2. From this branch of knowledge we alſo learn by what means or laws the Almighty carries on, and continues the wonderful harmony, order, and connexion obſervable throughout the planetary ſyſtem; and are led by very powerful arguments to form this pleaſing deduction, that minds capable

* Dr. YOUNG's Night Thoughts.

B of

of ſuch deep reſearches, not only derive their origin from that adorable Being, but are alſo incited to aſpire after a more perfect knowledge of his nature, and a ſtricter conformity to his will.

The Earth but a point as ſeen from the Sun.

3. By Aſtronomy we diſcover that the Earth is at ſo great a diſtance from the Sun, that if ſeen from thence it would appear no bigger than a point; although its circumference is known to be 25,020 miles. Yet that diſtance is ſo ſmall, compared with the Earth's diſtance from the Fixed Stars, that if the orbit in which the Earth moves round the Sun were ſolid, and ſeen from the neareſt Star, it would likewiſe appear no bigger than a point, although it is about 162 millions of miles in diameter. For the Earth in going round the Sun is 162 millions of miles nearer to ſome of the Stars at one time of the year, than at another; and yet their apparent magnitudes, ſituations, and diſtances from one another ſtill remain the ſame; and a teleſcope which magnifies above 200 times, does not ſenſibly magnify them: which proves them to be at leaſt 400 thouſand times farther from us than we are from the Sun.

4. It is not to be imagined that all the Stars are placed in one concave ſurface, ſo as to be equally diſtant from us; but that they are placed at immenſe diſtances from one another through unlimited ſpace. So that there may be as great a diſtance between any two neighbouring Stars, as between our Sun and thoſe which are neareſt to him.

The Stars are Suns,

Therefore an Obſerver, who is neareſt any fixed Star, will look upon it alone as a real Sun; and conſider the reſt as ſo many ſhining points, placed at equal diſtances from him in the Firmament.

and innumerable,

5. By the help of teleſcopes we diſcover thouſands of Stars, which are inviſible to the bare eye; and the better our glaſſes are, ſtill the more become viſible: ſo that we can ſet no limits either to their number or their diſtances. The celebrated Huygens carried his thoughts ſo far, as to believe it not

not impoſſible that there may be Stars at ſuch inconceivable diſtances, that their light has not yet reached the Earth ſince its creation; although the velocity of light be a million of times greater than the velocity of a cannon ball, as ſhall be demonſtrated afterward, § 197. 216: and, as Mr. ADDISON very juſtly obſerves, this thought is far from being extravagant, when we conſider that the Univerſe is the work of infinite power, prompted by infinite goodneſs; having an infinite ſpace to exert itſelf in; ſo that our imaginations can ſet no bounds to it.

6. The Sun appears very bright and large in compariſon of the Fixed Stars, becauſe we keep conſtantly near the Sun, in compariſon of our immenſe diſtance from the Stars. For, a ſpectator placed as near to any Star as we are to the Sun, would ſee that Star a body as large and bright as the Sun appears to us: and a ſpectator, as far diſtant from the Sun as we are from the Stars, would ſee the Sun as ſmall as we ſee a Star, diveſted of all its circumvolving planets; and would reckon it one of the Stars in numbering them.

Why the Sun appears bigger than the Stars.

7. The Stars being at ſuch immenſe diſtances from the Sun, cannot poſſibly receive from him ſo ſtrong a light as they ſeem to have; nor any brightneſs ſufficient to make them viſible to us. For the Sun's rays muſt be ſo ſcattered and diſſipated before they reach ſuch remote objects, that they can never be tranſmitted back to our eyes, ſo as to render theſe objects viſible by reflection. The Stars therefore ſhine with their own native and unborrowed luſtre, as the Sun does; and ſince each particular Star, as well as the Sun, is confined to a particular portion of ſpace, it is plain that the Stars are of the ſame nature with the Sun.

The Stars are not enlightened by the Sun.

8. It is no ways probable that the Almighty, who always acts with infinite wiſdom, and does nothing in vain, ſhould create ſo many glorious Suns, fit for ſo many important purpoſes, and place them

at

at fuch diftances from one another, without proper objects near enough to be benefited by their influences. Whoever imagines they were created only to give a faint glimmering light to the inhabitants of this Globe, muft have a very fuperficial knowledge of Aftronomy, and a mean opinion of the Divine Wifdom: fince, by an infinitely lefs exertion of creating power, the Deity could have given our Earth much more light by one fingle additional Moon.

They are probably furrounded by Planets.

9. Inftead then of one Sun and one World only in the Univerfe, as the unfkilful in Aftronomy imagine, *that* Science difcovers to us fuch an inconceivable number of Suns, Syftems, and Worlds, difperfed through boundlefs Space, that if our Sun, with all the Planets, Moons, and Comets, belonging to it, were annihilated, they would be no more miffed, by an eye that could take in the whole Creation, than a grain of fand from the fea-fhore. The fpace they poffefs being comparatively fo fmall, that it would fcarce be a fenfible blank in the Univerfe, although Saturn, the outermoft of our planets, revolves about the Sun in an Orbit of 4884 millions of miles in circumference *, and fome of our Comets make excurfions upward of ten thoufand millions of miles beyond Saturn's Orbit; and yet, at that amazing diftance, they are incomparably nearer to the Sun than to any of the Stars; as is evident from their keeping clear of the attractive power of all the Stars, and returning periodically by virtue of the Sun's attraction.

The ftellar Planets may be habitable,

10. From what we know of our own Syftem, it may be reafonably concluded that all the reft are with equal wifdom contrived, fituated, and provided with accommodations for rational inhabitants. Let us therefore take a furvey of the Syftem to which we belong; the only one accef-

* The Georgian Planet, difcovered fince Mr. Fergufon's time, revolves round the Sun in an Orbit 5673 millions of miles in circumference.

fible

ſible to us; and from thence we ſhall be the better enabled to judge of the nature and end of the other Syſtems of the Univerſe. For although there is almoſt an infinite variety in the parts of the Creation, which we have opportunities of examining, yet there is a general analogy running through and connecting all the parts into one ſcheme, one deſign, one whole!

11. And then, to an attentive conſiderer, it will appear highly probable, that the Planets of our Syſtem, together with their attendants called Satellites or Moons, are much of the ſame nature with our Earth, and deſtined for the like purpoſes. For they are ſolid opaque Globes, capable of ſupporting animals and vegetables. Some of them are bigger, ſome leſs, and ſome much about the ſize of our Earth. They all circulate round the Sun, as the Earth does, in a ſhorter or longer time, according to their reſpective diſtances from him; and have, where it would not be inconvenient, regular returns of ſummer and winter, ſpring and autumn. They have warmer and colder climates, as the various productions of our Earth require: and, in ſuch as afford a poſſibility of diſcovering it, we obſerve a regular motion round their axis like that of our Earth, cauſing an alternate return of day and night; which is neceſſary for labour, reſt, and vegetation, and that all parts of their ſurfaces may be expoſed to the rays of the Sun. as our Solar Planets are.

12. Such of the Planets as are fartheſt from the Sun, and therefore enjoy leaſt of his light, have that deficiency made up by ſeveral Moons, which conſtantly accompany, and revolve about them as our Moon revolves about the Earth. The remoteſt Planet has, over and above, a broad ring encompaſſing it; which like a lucid Zone in the Heavens reflects the Sun's light very copiouſly on that Planet: ſo that if the remoter Planets have the Sun's light fainter by day than we, they have The fartheſt from the Sun have moſt Moons to enlighten their nights.

an addition made to it morning and evening by one or more of their moons, and a greater quantity of light in the night-time.

Our Moon mountainous like the Earth.

13. On the ſurface of the Moon, becauſe it is nearer to us than any other of the celeſtial Bodies are, we diſcover a nearer reſemblance of our Earth. For, by the aſſiſtance of teleſcopes, we obſerve the Moon to be full of high mountains, large valleys, and deep cavities. Theſe ſimilarities leave us no room to doubt, but that all the Planets and Moons, in the Syſtem, are deſigned as commodious habitations for creatures endowed with capacities of knowing and adoring their beneficent Creator.

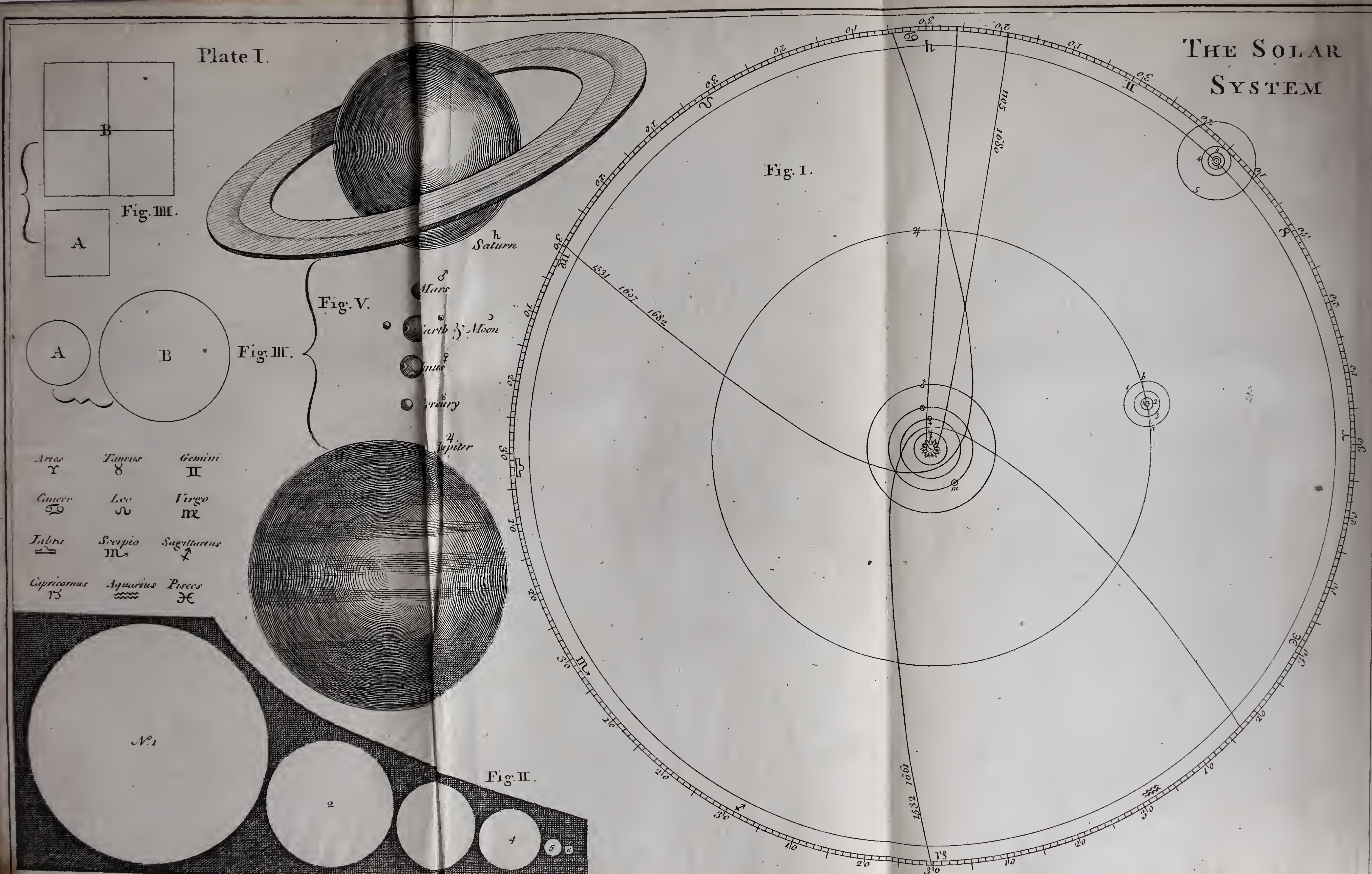
14. Since the Fixed Stars are prodigious ſpheres of fire, like our Sun, and at inconceivable diſtances from one another, as well as from us, it is reaſonable to conclude they are made for the ſame purpoſes that the Sun is; each to beſtow light, heat, and vegetation on a certain number of inhabited Planets, kept by gravitation within the ſphere of its activity.

Numberleſs Suns and Worlds.

15. What an auguſt, what an amazing conception, if human imagination can conçeive it, does this give of the works of the Creator! Thouſands of thouſands of Suns, multiplied without end, and ranged all around us, at immenſe diſtances from each other, attended by ten thouſand times ten thouſand worlds, all in rapid motion, yet calm, regular, and harmonious, invariably keeping the paths preſcribed them; and theſe worlds peopled with myriads of intelligent beings, formed for endleſs progreſſion in perfection and felicity!

16. If ſo much power, wiſdom, goodneſs, and magnificence is diſplayed in the material Creation, which is the leaſt conſiderable part of the Univerſe, how great, how wiſe, how good muſt HE be, who made and governs the Whole!

CHAP.



J. Ferguson delin.

J. Mynde sculp.

CHAP. II.

A brief Deſcription of the SOLAR SYSTEM.

17. THE Sun, with the Planets and Comets which move round him as their center, conſtitute the Solar Syſtem. Thoſe Planets which are near the Sun not only finiſh their circuits ſooner, but likewiſe move faſter in their reſpective Orbits, than thoſe which are more remote from him. Their motions are all performed from weſt to eaſt, in Orbits nearly circular. Their names, diſtances, bulks, and periodical revolutions, are as follow: PLATE I. Fig. I. The Solar Syſtem.

18. The Sun ☉, an immenſe globe of fire, is placed near the common center, or rather in the lower* focus, of the Orbits of all the Planets and Comets†; and turns round his axis in 25 days 6 hours, as is evident by the motions of ſpots ſeen on his ſurface. His diameter is computed to be 763,000 miles; and, by the various attractions of the circumvolving Planets, he is agitated by a The Sun. Fig. I.

* If the two ends of a thread be tied together, and the thread be then thrown looſely round two pins ſtuck in a table, and moderately ſtretched by the point of a black-lead pencil carried round by an even motion and light preſſure of the hand, an oval or ellipſis will be deſcribed; and the points where the pins are fixed are called the *foci* or focuſes of the ellipſis. The Orbits of all the Planets are elliptical, and the Sun is placed in or near one of the *foci* of each of them: and *that* in which he is placed, is called the *lower focus*.

† Aſtronomers are not far from the truth when they reckon the Sun's center to be in the lower focus of all the Planetary Orbits. Though, ſtrictly ſpeaking, if we conſider the focus of Mercury's Orbit to be in the Sun's center, the focus of Venus's Orbit will be in the common center of gravity of the Sun and Mercury; the focus of the Earth's Orbit in the common center of gravity of the Sun, Mercury, and Venus; the focus of the Orbit of Mars in the common center of gravity of the Sun, Mercury, Venus, and the Earth; and ſo of the reſt. Yet the focuſes of the Orbits of all the Planets, except Saturn, will not be ſenſibly removed from the center of the Sun; nor will the focus of Saturn's Orbit recede ſenſibly from the common center of gravity of the Sun and Jupiter.

 ſmall

PLATE I. ſmall motion round the center of gravity of the Syſtem. All the Planets, as ſeen from him, move the ſame way, and according to the order of the Signs in the graduated Circle ♈ ♉ ♊ ♋, &c. which repreſents the great Ecliptic in the Heavens: but, as ſeen from any one Planet, the reſt appear ſometimes to go backward, ſometimes forward, and ſometimes to ſtand ſtill; not in circles nor ellipſes, but* in looped curves, which never return into themſelves. The Comets come from all parts of the Heavens, and move in all ſorts of directions.

The Axes of the Planets, what.

19. Having mentioned the Sun's turning round his axis, and as there will be frequent occaſion to ſpeak of the like motion of the Earth and other Planets, it is proper here to inform the young *Tyro* in Aſtronomy, that neither the Sun nor Planets have material axes to turn upon, and ſupport them, as in the little imperfect machines contrived to repreſent them. For the axis of a Planet is a line conceived to be drawn through its center, about which it revolves as if on a real axis. The extremities of this line, terminating in oppoſite points of the Planet's ſurface, are called its *Poles*. That which points toward the *northern* part of the Heavens, is called the *North Pole*; and the other, pointing toward the *ſouthern* part, is called the *South Pole*. A bowl whirled from one's hand into the open air, turns round ſuch a line within itſelf, while it moves forward; and ſuch are the lines we mean, when we ſpeak of the Axes of the Heavenly bodies.

Their Orbits are not in the ſame plane with the Ecliptic.

20. Let us ſuppoſe the Earth's Orbit to be a thin, even, ſolid plane; cutting the Sun through the center, and extended out as far as the Starry Heavens, where it will mark the great Circle called the *Ecliptic*. This Circle we ſuppoſe to be divided into 12 equal parts, called *Signs*; each Sign into 30 equal parts, called *Degrees*; each Degree into 60 equal parts, called *Minutes*; and every Minute into

* As repreſented in Plate III. Fig. I. and deſcribed § 138.

PLATE I.

into 60 equal parts, called *Seconds:* so that a Second is the 60th part of a Minute; a Minute the 60th part of a Degree; and a Degree the 360th part of a Circle, or 30th part of a Sign. The Planets of the Orbits of all the other Planets likewise cut the Sun in halves; but extended to the Heavens, form Circles different from one another, and from the Ecliptic; one half of each being on the north side, and the other on the south side of it. Consequently the Orbit of each Planet crosses the Ecliptic in two opposite points, which are called the Planet's *Nodes*. These Nodes are all in different parts of the Ecliptic; and therefore, if the planetary Tracks remained visible in the Heavens, they would in some measure resemble the different ruts of waggon-wheels crossing one another in different parts, but never going far asunder. That Node, or Intersection of the Orbit of any Planet with the Earth's Orbit, from which the Planet ascends northward above the Ecliptic, is called the *Ascending Node* of the Planet: and the other, which is directly opposite thereto, is called its *Descending Node*. Saturn's Ascending Node* is in 21 deg. 32 min. of Cancer ♋, Jupiter's in 8 deg. 49 min. of the same Sign, Mars's in 18 deg. 22 min. of Taurus ♉, Venus's in 14 deg. 44 min. of Gemini ♊, and Mercury's in 16 deg. 2 min. of Taurus. Here we consider the Earth's Orbit as the standard, and the Orbits of all the other Planets as oblique to it.

Their Nodes.

Where situated.

21. When we speak of the Planets Orbits, all that is meant is their paths through the open and unresisting Space in which they move; and are kept in by the attractive power of the Sun, and the projectile force impressed upon them at first: between which power and force there is so exact an adjustment, that they continue in the same tracks without any solid Orbits to confine them.

The Planets Orbits, what.

* In the year 1790.

22. MER-

PLATE I. Mercury. Fig. I.

22. MERCURY, the neareſt Planet to the Sun, goes round him in the circle marked ☿, in 87 days 23 hours of our time nearly; which is the length of his year. But being ſeldom ſeen, and no ſpots appearing on his ſurface or diſc, the time of his rotation on his axis, or the length of his days and nights is as yet unknown. His diſtance from the Sun is computed to be 32 millions of miles, and his diameter 2600. In his courſe round the Sun, he moves at the rate of 95 thouſand miles every hour. His light and heat from the Sun are almoſt ſeven times as great as ours; and the Sun appears to him almoſt ſeven times as large as to us. The great heat on this Planet is no argument againſt its being inhabited; ſince the Almighty could as eaſily ſuit the bodies and conſtitutions of its inhabitants to the heat of their dwelling, as he has done ours to the temperature of our Earth. And it is very probable that the people there have ſuch an opinion of us, as we have of the inhabitants of Jupiter and Saturn; namely, that we muſt be intolerably cold, and have very little light at ſo great a diſtance from the Sun.

May be inhabited.

Has like phaſes with the Moon.

23. This Planet appears to us with all the various phaſes of the Moon, when viewed at different times by a good teleſcope: ſave only that he never appears quite Full, becauſe his enlightened ſide is never turned directly toward us, but when he is ſo near the Sun as to be loſt to our ſight in its beams. And, as his enlightened ſide is always toward the Sun, it is plain that he ſhines not by any light of his own; for if he did, he would conſtantly appear round. That he moves about the Sun in an Orbit within the Earth's Orbit, is alſo plain (as will be more largely ſhewn by and by, § 141, *& ſeq.*) becauſe he is never ſeen oppoſite to the Sun, nor above 56 times the Sun's breadth from his center.

24. His

PLATE I. His Orbit and Nodes.

24. His Orbit is inclined ſeven degrees to the Ecliptic; and *that* Node, § 20, from which he aſcends Northward above the Ecliptic, is in the 16th degree of Taurus; and the oppoſite Node is in the 16th degree of Scorpio. The Earth is in theſe points on the 7th of *November* and 5th of *May*; and when Mercury comes to either of his Nodes at his * inferior Conjunction about theſe times, he will appear to paſs over the diſc or face of the Sun, like a dark round ſpot. But in all other parts of his Orbit his Conjunctions are inviſible, becauſe he either goes above or below the Sun.

When he will be ſeen as if upon the Sun.

25. Mr. WHISTON has given us an account of ſeveral periods at which Mercury may be ſeen on the Sun's diſc, *viz.* In the year 1782, *Nov.* 12th, at 3 h. 44 m. in the afternoon; 1786, *May* 4th, at 6 h. 57 m. in the forenoon; 1789, *Nov.* 5th, at 3 h. 55 m. in the afternoon; and 1799, *May* 7th, at 2 h. 34 m. in the afternoon. There will be ſeveral intermediate Tranſits, but none of them viſible at *London*.

Venus. Fig. I.

26. VENUS, the next Planet in order, is computed to be 59 millions of miles from the Sun; and by moving at the rate of 69 thouſand miles every hour in her Orbit, in the circle marked ♀, ſhe goes round the Sun in 224 days 17 hours of our time, nearly; in which, though it be the full length of her year, ſhe has only 9¼ days, according to BIANCHINI's obſervations†; ſo that, to her, every

* When he is between the Earth and the Sun in the nearer part of his Orbit.

† The elder Caſſini had concluded from obſervations made by himſelf in 1667, that Venus revolved on her axis in a little more than 23 h. becauſe in 24 h. he found that a ſpot on her ſurface was about 15° more advanced than it was the day before; and it appeared to him that the ſpot was very ſenſibly advanced in a quarter of an hour. In 1728, Bianchini publiſhed a ſplendid work, in folio, at Rome, entitled *Heſperi et Phoſphori nova phænomena*; in which are the obſervations here referred

PLATE I. every day and night together is as long as $24\frac{1}{3}$ days and nights with us. This odd quarter of a day in every year makes every fourth year a leap-year to Venus; as the like does to our Earth. Her diameter is 7906 miles; and by her diurnal motion the inhabitants about her Equator are carried 43 miles every hour, beside the 69,000 above-mentioned.

Her Orbit lies between the Earth and Mercury.

27. Her Orbit includes that of Mercury within it; for at her greatest Elongation, or apparent distance from the Sun, she is 96 times the breadth of that luminary from his center; which is almost double of Mercury's greatest Elongation. Her Orbit is included by the Earth's; for if it were not, she might be seen as often in Opposition to the Sun, as she is in Conjunction with him; but she was never seen 90 degrees, or a fourth part of a Circle, from the Sun.

She is our morning and evening Star by turns.

28. When Venus appears west of the Sun, she rises before him in the morning, and is called the *Morning Star*: when she appears east of the Sun, she shines in the evening after he sets, and is then called the *Evening Star*: being each in its turn for 290 days. It may perhaps be surprising at first, that Venus should keep longer on the east or west of the Sun, than the whole time of her Period round him. But the difficulty vanishes when we consider that the Earth is all the while going round the Sun the same way, though not so quick as Venus: and therefore her relative motion to

referred to. Bianchini agrees perfectly with Cassini that the spots, which are seen on the surface of Venus, advanced about 15° in 24 h. but he asserts that he could not perceive they had made any advance in 3 h. and therefore concludes, that instead of making one complete revolution and 15° of another, as Cassini conjectured, in 24 h. those spots advance but the odd 15° in that time, and that the time of a revolution is somewhat more than 24 days. The arguments in favour of the two hypotheses are very equal; but almost every astronomer, except Mr. Ferguson, has adopted Cassini's.

the

the Earth muſt in every period be as much ſlower than her abſolute motion in her Orbit, as the Earth during that time advances forward in the Ecliptic; which is 220 degrees. To us ſhe appears through a teleſcope in all the various ſhapes of the Moon.

29. The Axis of Venus is inclined 75 degrees to the Axis of her Orbit; which is 51½ degrees more than our Earth's Axis is inclined to the Axis of the Ecliptic: and therefore her ſeaſons vary much more than ours do. The North Pole of her Axis inclines toward the 20th degree of Aquarius, our Earth's to the beginning of Cancer; conſequently the northern parts of Venus have ſummer in the Signs where thoſe of our Earth have winter, and *vice verſâ.*

Remarkable appearances.

30. The * artificial day at each Pole of Venus is as long as 112½ † natural days on our Earth.

Her Tropics and Polar Circles how ſituated.

31. The Sun's greateſt Declination on each ſide of her Equator amounts to 75 degrees; therefore her ‡ Tropics are only 15 degrees from her Poles; and her ‖ Polar Circles as far from her Equator. Conſequently the Tropics of Venus are between her Polar Circles and her Poles; contrary to what thoſe of our Earth are.

The Sun's daily Courſe,

32. As her annual Revolution contains only 9¼ of her days, the Sun will always appear to go through a whole Sign, or twelfth part of her Orbit, in a little more than three quarters of her

* The time between the Sun's riſing and ſetting.

† One entire revolution, or 24 hours.

‡ Theſe are leſſer circles parallel to the Equator, and as many degrees from it, toward the Poles, as the Axis of the Planet is inclined to the Axis of its Orbit. When the Sun is advanced ſo far north or ſouth of the Equator, as to be directly over either Tropic, he goes no farther; but returns toward the other.

‖ Theſe are leſſer circles round the Poles, and as far from them as the Tropics are from the Equator. The Poles are the very north and ſouth points of the Planet.

natural

natural day, or nearly in 18¼ of our days and nights.

and great Declination.

33. Becauſe her day is ſo great a part of her year, the Sun changes his Declination in one day ſo much, that if he paſſes vertically, or directly over head of any given place on the Tropic, the next day he will be 26 degrees from it: and whatever place he paſſes vertically over when in the Equator, one day's revolution will remove him 36¼ degrees from it. So that the Sun changes his Declination every day in Venus about 14 degrees more, at a mean rate, than he does in a quarter of a year on our Earth. This appears to be providentially ordered, for preventing the too great effects of the Sun's heat (which is twice as great on Venus as on the Earth) ſo that he cannot ſhine perpendicularly on the ſame places for two days together; and on that account, the heated places have time to cool.

To determine the points of the Compaſs at her Poles.

34. If the inhabitants about the North Pole of Venus fix their South, or Meridian Line, through that part of the Heavens where the Sun comes to his greateſt Height, or North Declination, and call thoſe the eaſt and weſt points of their Horizon, which are 90 degrees on each ſide from that point where the Horizon is cut by the Meridian Line, theſe inhabitants will have the following remarkable appearances.

The Sun will riſe 22½ degrees* north of the eaſt, and going on 112½ degrees, as meaſured on the plane of the† Horizon, he will croſs the Meridian at an altitude of 12½ degrees; then making an entire revolution without ſetting, he will croſs it again at an altitude of 48½ degrees; at the next revolution he will croſs the Meridian as he comes to his greateſt height and declination, at the

* A Degree is a 360th part of any Circle. See § 21.

† The limit of any inhabitant's view, where the Sky ſeems to touch the Planet all round him.

altitude

altitude of 75 degrees; being then only 15 degrees from the Zenith, or that point of the Heavens which is directly over head: and thence he will descend in the like spiral manner; crossing the Meridian first at the altitude of $48\frac{1}{2}$ degrees; next at the altitude of $12\frac{1}{2}$ degrees; and going on thence $112\frac{1}{2}$ degrees, he will set $22\frac{1}{2}$ degrees north of the west; so that, after having been $4\frac{5}{8}$ revolutions above the Horizon, he descends below it to exhibit the like appearances at the South Pole.

Surprising appearances at her Poles.

35. At each Pole, the Sun continues half a year without setting in summer, and as long without rising in winter; consequently the polar inhabitants of Venus have only one day and one night in the year; as it is at the Poles of our Earth. But the difference between the heat of summer and cold of winter, or of mid-day and mid-night, on Venus, is much greater than on the Earth: because on Venus, as the Sun is for half a year together above the Horizon of each Pole in its turn, so he is for a considerable part of that time near the Zenith; and during the other half of the year always below the Horizon, and for a great part of that time at least 70 degrees from it. Whereas, at the Poles of our Earth, although the Sun is for half a year together above the Horizon; yet he never ascends above, nor descends below it, more than $23\frac{1}{2}$ degrees. When the Sun is in the Equinoctial, or in that Circle which divides the northern half of the Heavens from the southern, he is seen with one half of his Disc above the Horizon of the North Pole, and the other half above the Horizon of the South Pole; so that his center is in the Horizon of both Poles: and then descending below the Horizon of one, he ascends gradually above that of the other. Hence, in a year, each Pole has one spring, one autumn, a summer as long as them both, and a winter equal in length to the other three seasons.

At her Polar Circles.

36. At the Polar Circles of Venus, the ſeaſons are much the ſame as at the Equator, becauſe there are only 15 degrees between them, § 31; only the winters are not quite ſo long, nor the ſummers ſo ſhort: but the four ſeaſons come twice round every year.

At her Tropics.

37. At Venus's Tropics, the Sun continues for about fifteen of our weeks together without ſetting in ſummer; and as long without riſing in winter. While he is more than 15 degrees from the Equator, he neither riſes to the inhabitants of the one Tropic, nor ſets to thoſe of the other: whereas, at our terreſtrial Tropics, he riſes and ſets every day of the year.

38. At Venus's Tropics, the Seaſons are much the ſame as at her Poles; only the ſummers are a little longer, and the winters a little ſhorter.

At her Equator.

39. At her Equator, the days and nights are always of the ſame length; and yet the diurnal and nocturnal Arches are very different, eſpecially when the Sun's declination is about the greateſt: for then, his meridian altitude may ſometimes be twice as great as his midnight depreſſion, and at other times the reverſe. When the Sun is at his greateſt declination, either north or ſouth, his rays are as oblique at Venus's Equator, as they are at *London* on the ſhorteſt day of winter. Therefore, at her Equator there are two winters, two ſummers, two ſprings, and two autumns every year. But becauſe the Sun ſtays for ſome time near the Tropics, and paſſes ſo quickly over the Equator, every winter there will be almoſt twice as long as ſummer: the four ſeaſons returning twice in that time, which conſiſts only of 9¼ days.

40. Thoſe parts of Venus which lie between the Poles and Tropics, and between the Tropics and Polar Circles, and alſo between the Polar Circles and Equator, partake more or leſs of the Phenomena of theſe Circles, as they are more or leſs diſtant from them.

4 41. From

41. From the quick change of the Sun's declination it happens, that if he riſes due eaſt on any day, he will not ſet due weſt on that day, as with us; for if the place where he riſes due eaſt be on the Equator, he will ſet on that day almoſt weſt-north-weſt; or about 18½ degrees north of the weſt. But if the place be in 45 degrees north latitude, then on the day that the Sun riſes due eaſt he will ſet north-weſt by weſt, or 33 degrees north of the weſt. And in 62 degrees north latitude, when he riſes in the eaſt, he ſets not in that revolution, but juſt touches the Horizon 10 degrees to the weſt of the north point: and aſcends again, continuing for 3¼ revolutions above the Horizon without ſetting. Therefore no place has the forenoon and afternoon of the ſame day equally long, unleſs it be on the Equator, or at the Poles.

Great difference of the Sun's amplitude at riſing and ſetting.

42. The Sun's altitude at noon, or any other time of the day, and his amplitude at riſing and ſetting, being very different at places on the ſame parallel of latitude, according to the different longitudes of thoſe places, the longitude will be almoſt as eaſily found on Venus, as the latitude is found on the Earth: which is an advantage we can never have, becauſe the daily change of the Sun's declination is by much too ſmall for that important purpoſe.

The longitude of places eaſily found in Venus.

43. On this Planet, where the Sun croſſes the Equator in any year, he will have 9 degrees of declination from that place on the ſame day and hour next year; and will croſs the Equator 90 degrees farther to the weſt; which makes the time of the Equinox a quarter of a day (or about ſix of our days) later every year. Hence, although the ſpiral in which the Sun's motion is performed be of the ſame ſort every year, yet it will not be the very ſame, becauſe the Sun will not paſs vertically over the ſame places till four annual revolutions are finiſhed.

Her Equinoxes ſhift a quarter of a day forward every year.

Every fourth year a leap year to Venus.

44. We may ſuppoſe that the inhabitants of Venus will be careful to add a day to ſome particular part of every fourth year; which will keep the ſame ſeaſons to the ſame days. For, as the great annual change of the Equinoxes and Solſtices ſhifts the ſeaſons a quarter of a day every year; they would be ſhifted through all the days of the year in 36 years. But by means of this intercalary day, every fourth year will be a leap-year, which will bring her time to an even reckoning, and keep her Calendar always right.

When ſhe will appear on the Sun.

45. Venus's Orbit is inclined 3 degrees 24 minutes to the Earth's; and croſſes it in the 15th degree of Gemini and of Sagittarius; and therefore, when the Earth is about theſe points of the Ecliptic at the time that Venus is in her inferior conjunction, ſhe will appear like a ſpot on the Sun, and afford a more certain method of finding the diſtances of all the Planets from the Sun, than any other yet known. But theſe appearances happen very ſeldom; and will be only twice viſible at *London* for one hundred and ten years to come. The firſt time will be in 1761, *June* the 6th, in the morning; and the ſecond in 1769, on the 3d of *June* in the evening. Excepting ſuch Tranſits as theſe, ſhe ſhews the ſame appearances to us regularly every eight years; her Conjunctions, Elongations, and Times of riſing and ſetting, being very nearly the ſame, on the ſame days as before.

She may have a Moon, although we cannot ſee it.

46. Venus may have a Satellite or Moon, although it be undiſcovered by us: which will not appear very ſurpriſing, if we conſider how inconveniently we are placed for ſeeing it. For its enlightened ſide can never be fully turned toward us, but when Venus is beyond the Sun; and then, as Venus appears little bigger than an ordinary Star, her Moon may be too ſmall to be perceived at ſuch a diſtance. When ſhe is between us and the Sun, her full Moon has its dark ſide toward us; and then we cannot ſee it any more than we can

can our own Moon at the time of Change. When Venus is at her greateſt Elongation, we have but one half of the enlightened ſide of her full Moon toward us; and even then it may be too far diſtant to be ſeen by us. But if ſhe has a Moon, it may certainly be ſeen with her upon the Sun, in the year 1761; unleſs its Orbit be conſiderably inclined to the Ecliptic: for if it ſhould be in conjunction or oppoſition at that time, we can hardly imagine that it moves ſo ſlow as to be hid by Venus all the ſix hours that ſhe will appear on the Sun's Diſc *.

47. The EARTH is the next Planet above Venus in the Syſtem. It is 82 millions of miles from the Sun, and goes round him, in the circle ⊕, in 365 days 5 hours 49 minutes, from any Equinox or Solſtice to the ſame again: but from any fixed Star to the ſame again, as ſeen from the Sun, in 365 days 6 hours and 9 minutes; the former being the length of the Tropical year, and the latter the length of the Sydereal. It travels at the rate of 58 thouſand miles every hour; which motion, though 120 times ſwifter than that of a cannon-ball, is little more than half as ſwift as Mercury's motion in his Orbit. The Earth's diameter is 7970 miles; and by turning round its Axis every 24 hours from Weſt to Eaſt, it cauſes an apparent diurnal motion of all the heavenly Bodies from Eaſt to Weſt. By this rapid motion of the Earth on its Axis, the inhabitants about the Equator are carried 1042 miles every hour, while thoſe on the parallel of *London* are carried only about 580, beſide the 58 thouſand miles by the annual motion above-mentioned, which is common to all places whatever.

The Earth. Fig. 1.

Its diurnal and annual motion.

48. The Earth's Axis makes an angle of $23\frac{1}{2}$ degrees with the Axis of its Orbit; and keeps

Inclination of its Axis.

* Both her tranſits are over ſince this was written, and no Satellite was ſeen with Venus on the Sun's Diſc.

always the ſame oblique direction; inclining toward the ſame fixed Stars * throughout its annual courſe, which cauſes the returns of ſpring, ſummer, autumn, and winter; as will be explained at large in the tenth Chapter.

A proof of its being round.

49. The Earth is round like a globe; as appears, 1. By its ſhadow in Eclipſes of the Moon; which ſhadow is always bounded by a circular line, § 314. 2. By our ſeeing the maſts of a ſhip while the hull is hid by the convexity of the water. 3. By its having been ſailed round by many navigators. The hills take off no more from the roundneſs of the Earth in compariſon, than grains of duſt do from the roundneſs of a common Globe.

It's number of ſquare miles.

50. The ſeas and unknown parts of the Earth (by a meaſurement of the beſt Maps) contain 160 million 522 thouſand and 26 ſquare miles; the inhabited parts 38 million 990 thouſand 569: *Europe* 4 million 456 thouſand and 65; *Aſia* 10 million 768 thouſand 823; *Africa* 9 million 654 thouſand 807; *America* 14 million 110 thouſand 874. In all, 199 million 512 thouſand 595; which is the number of ſquare miles on the whole ſurface of our Globe.

The proportion of land and ſea.

51. Dr. Long, in the firſt volume of his Aſtronomy, p. 168, mentions an ingenious and eaſy method of finding nearly what proportion the land bears to the ſea; which is, to take the papers of a large terreſtrial globe, and after ſeparating the land from the ſea with a pair of ſciſſars, to weigh them carefully in ſcales. This ſuppoſes the globe to be exactly delineated, and the papers all of equal thickneſs. The Doctor made the experiment on

* This is not ſtrictly true, as will appear when we come to treat of the Receſſion of the Equinoctial Points in the Heavens, § 246; which receſſion is equal to the deviation of the Earth's Axis from its paralleliſm; but this is rather too ſmall to be ſenſible in an age, except to thoſe who make very nice obſervations.

 the

the papers of Mr. SENEX's ſeventeen-inch globe; and found that the ſea-papers weighed 349 grains, and the land only 124: by which it appears that almoſt three-fourth parts of the ſurface of our Earth between the Polar Circles are covered with water, and that little more than one-fourth is dry land. The Doctor omitted weighing all within the Polar Circles; becauſe there is no certain meaſurement of the land within them, ſo as to know what proportion it bears to the ſea.

52. The MOON is not a Planet, but only a Satellite or Attendant of the Earth; going round the Earth from Change to Change in 29 days 12 hours and 44 minutes; and round the Sun with it every year. The Moon's diameter is 2180 miles; and her diſtance from the Earth's center 240 thouſand. She goes round her Orbit in 27 days 7 hours 43 minutes, moving about 2290 miles every hour; and turns round her Axis exactly in the time that ſhe goes round the Earth, which is the reaſon of her keeping always the ſame ſide toward us, and that her day and night taken together is as long as our lunar month. The Moon.

53. The Moon is an opaque Globe like the Earth, and ſhines only by reflecting the light of the Sun: therefore while that half of her which is toward the Sun is enlightened, the other half muſt be dark and inviſible. Hence, ſhe diſappears when ſhe comes between us and the Sun; becauſe her dark ſide is then toward us. When ſhe is gone a little way forward, we ſee a little of her enlightened ſide: which ſtill increaſes to our view, as ſhe advances forward, until ſhe comes to be oppoſite to the Sun; and then her whole enlightened ſide is toward the Earth, and ſhe appears with a round illumined Orb, which we call the *Full-Moon*; her dark ſide being then turned away from the Earth. From the Full ſhe ſeems to decreaſe gradually as ſhe goes through the other half of her Her phaſes.

 courſe;

courſe; ſhewing us leſs and leſs of her enlightened ſide every day, till her next change or conjunction with the Sun, and then ſhe diſappears as before.

A proof that ſhe ſhines not by her own light.

54. This continual change of the Moon's phaſes demonſtrates that ſhe ſhines not by any light of her own; for if ſhe did, being globular, we ſhould always ſee her with a round full Orb like the Sun. Her Orbit is repreſented in the ſcheme by the little circle *m*, upon the Earth's Orbit ⊕; but it is drawn fifty times too large in proportion to the Earth's; and yet is almoſt too ſmall to be ſeen in the Diagram.

Fig. I.

One half of her always enlightened.

55. The Moon has ſcarce any difference of ſeaſons; her Axis being almoſt perpendicular to the Ecliptic. What is very ſingular, one half of her has no darkneſs at all; the Earth conſtantly affording it a ſtrong light in the Sun's abſence; while the other half has a fortnight's darkneſs and a fortnight's light by turns.

Our Earth is her Moon.

56. Our Earth is a Moon to the Moon, waxing and weaning regularly, but appearing thirteen times as big, and affording her thirteen times as much light, as ſhe does to us. When ſhe changes to us the Earth appears full to her; and when ſhe is in her firſt quarter to us the Earth is in its third quarter to her; and *vice verſâ*.

57. But from one half of the Moon, the Earth is never ſeen at all: from the middle of the other half, it is always ſeen over head; turning round almoſt thirty times as quick as the Moon does. From the circle which limits our view of the Moon, only one half of the Earth's ſide next her is ſeen; the other half being hid below the Horizon of all places on that circle. To her, the Earth ſeems to be the biggeſt body in the Univerſe; for it appears thirteen times as big as ſhe does to us.

58. The Moon has no atmoſphere of any viſible denſity ſurrounding her as we have: for if ſhe had, we could never ſee her edge ſo well defined as it appears; but there would be a ſort of a miſt or

or hazineſs around her, which would make the Stars look fainter, when they are ſeen through it. But obſervation proves, that the Stars which diſappear behind the Moon, retain their full luſtre until they ſeem to touch her very edge, and then they vaniſh in a moment. This has been often obſerved by Aſtronomers, but particularly by CASSINI of the Star ♈ in the breaſt of Virgo, which appears ſingle and round to the bare eye; but through a refracting Teleſcope of 16 feet appears to be two Stars ſo near together, that the diſtance between them ſeems to be but equal to one of their apparent diameters. The Moon was obſerved to paſs over them on the 21ſt of *April* 1720, *N. S.* and as her dark edge drew near to them, it cauſed no change in their colour or ſituation. At 25 min. 14 ſec. paſt 12 at night, the moſt weſterly of theſe Stars was hid by the dark edge of the Moon: and in 30 ſeconds afterward, the moſt eaſterly Star was hid: each of them diſappearing behind the Moon in an inſtant, without any preceding diminution of magnitude or brightneſs; which by no means could have been the caſe if there were an Atmoſphere round the Moon; for then, one of the Stars falling obliquely into it before the other, ought by refraction to have ſuffered ſome change in its colour, or in its diſtance from the other Star which was not yet entered into the Atmoſphere. But no ſuch alteration could be perceived, though the obſervation was performed with the utmoſt attention to that particular; and was very proper to have made ſuch a diſcovery. The faint light which has been ſeen all round the Moon, in total Eclipſes of the Sun, has been obſerved, during the time of darkneſs, to have its center coincident with the center of the Sun; and was therefore much more likely to ariſe from the Atmoſphere of the Sun than from that of the Moon; for if it had been owing to the latter, its center would have gone along with the Moon's.

A proof of the Moon's having no Atmoſphere.

Nor Seas.

59. If there were ſeas in the Moon, ſhe could have no clouds, rains, nor ſtorms, as we have; becauſe ſhe has no ſuch Atmoſphere to ſupport the vapours which occaſion them. And every one knows, that when the Moon is above our Horizon in the night-time ſhe is viſible, unleſs the clouds of our Atmoſphere hide her from our view; and all parts of her appear conſtantly with the ſame clear, ſerene, and calm aſpect. But thoſe dark parts of the Moon, which were formerly thought to be ſeas, are now found to be only vaſt deep cavities, and places which reflect not the Sun's light ſo ſtrongly as others, having many caverns and pits whoſe ſhadows fall within them, and are always dark on the ſides next the Sun; which demonſtrates their being hollow: and moſt of theſe pits have little knobs like hillocks ſtanding within them, and caſting ſhadows alſo; which cauſe theſe places to appear darker than others which have fewer, or leſs remarkable caverns. All theſe appearances ſhew that there are no ſeas in the Moon; for if there were any, their ſurfaces would appear ſmooth and even, like thoſe on the Earth.

She is full of caverns and deep pits.

The Stars always viſible to the Moon.

60. There being no Atmoſphere about the Moon, the heavens in the day-time have the appearance of night to a Lunarian who turns his back toward the Sun; and when he does, the Stars appear as bright to him as they do in the night to us. For, it is entirely owing to our Atmoſphere that the Heavens are bright about us in the day.

The Earth a Dial to the Moon.

61. As the Earth turns round its Axis, the ſeveral continents, ſeas, and iſlands appear to the Moon's inhabitants like ſo many ſpots of different forms and brightneſs, moving over its ſurface; but much fainter at ſome times than others, as our clouds cover them or leave them. By theſe ſpots the Lunarians can determine the time of the Earth's diurnal motion, juſt as we do the motion of the Sun: and perhaps they meaſure their time by

by the motion of the Earth's ſpots; for they cannot have a truer dial.

62. The Moon's Axis is ſo nearly perpendicular to the Ecliptic, that the Sun never removes ſenſibly from her Equator: and the * obliquity of her Orbit, which is next to nothing as ſeen from the Sun, cannot cauſe the Sun to decline ſenſibly from her Equator. Yet her inhabitants are not deſtitute of means for aſcertaining the length of their year, though their method and ours muſt differ. For we can know the length of our year by the return of our Equinoxes; but the Lunarians, having always equal day and night, muſt have recourſe to another method; and we may ſuppoſe, they meaſure their year by obſerving when either of the Poles of our Earth begins to be enlightened, and the other to diſappear, which is always at our Equinoxes; they being conveniently ſituated for obſerving great tracks of land about our Earth's Poles, which are entirely unknown to us. Hence we may conclude, that the year is of the ſame abſolute length both to the Earth and Moon, though very different as to the number of days: we having $365\frac{1}{4}$ natural days, and the Lunarians only $12\frac{7}{19}$; every day and night in the Moon being as long as $29\frac{1}{2}$ on the Earth.

How the Lunarians may know the length of their year,

63. The Moon's inhabitants on the ſide next the Earth may as eaſily find the longitude of their places as we can find the latitude of ours. For the Earth keeping conſtantly, or very nearly ſo, over one Meridian of the Moon, the eaſt or weſt diſtances of places from that Meridian are as eaſily found, as we can find our diſtance from the Equator by the Altitude of our celeſtial Poles.

and the longitudes of their places.

* The Moon's Orbit croſſes the Ecliptic in two oppoſite points, called the Moon's Nodes; ſo that one half of her Orbit is above the Ecliptic, and the other half below it. The Angle of its Obliquity is $5\frac{1}{3}$ degrees,

64. The

PLATE I. Mars.

64. The Planet MARS is next in order, being the firſt above the Earth's Orbit. His diſtance from the Sun is computed to be 125 million of miles; and by travelling at the rate of 47 thouſand miles every hour, in the circle ♂, he goes round the Sun in 686 of our days and 23 hours, which is the length of his year, and contains 667¾ of his days; every day and night together being 40 minutes longer than with us. His diameter is 4444 miles, and by his diurnal rotation the inhabitants about his Equator are carried 556 miles every hour. His quantity of light and heat is equal but to one half of ours; and the Sun appears but half as big to him as to us.

Fig. I.

65. This planet being but a fifth part ſo big as the Earth, if any Moon attends him, it muſt be very ſmall, and has not yet been diſcovered by our beſt teleſcopes. He is of a fiery red colour, and by his Appulſes to ſome of the fixed Stars, ſeems to be encompaſſed by a very groſs Atmoſphere. He appears ſometimes gibbous, but never horned; which both ſhews that his Orbit includes the Earth's within it, and that he ſhines not by his own light.

His Atmoſphere and phaſes.

66. To Mars, our Earth and Moon appear like two Moons, a bigger and a leſs: changing places with one another, and appearing ſometimes horned, ſometimes half or three quarters illuminated, but never full; nor at moſt above one quarter of a degree from each other, although they are 240 thouſand miles aſunder.

How the other Planets appear to Mars.

67. Our Earth appears almoſt as big to Mars as Venus does to us, and at Mars it is never ſeen above 48 degrees from the Sun; ſometimes it appears to paſs over the Diſc of the Sun, and ſo do Mercury and Venus: But Mercury can never be ſeen from Mars by ſuch eyes as ours, unaſſiſted by proper inſtruments; and Venus will be as ſeldom ſeen as we ſee Mercury. Jupiter and Saturn are as viſible to Mars as to us. His Axis is perpendicular

pendicular to the Ecliptic, and his Orbit is inclined to it in an angle of 1 degree 50 minutes.

68. JUPITER, the biggeſt of all the Planets, is ſtill higher in the Syſtem, being about 426 million of miles from the Sun: and going at the rate of 25 thouſand miles every hour in his Orbit, which is repreſented by the circle ♃. He finiſhes his annual period in eleven of our years 314 days and 12 hours. He is above 1000 times as big as the Earth, for his diameter is 81,000 miles; which is more than ten times the diameter of the Earth. Jupiter. Fig. I.

69. Jupiter turns round his Axis in 9 hours 56 minutes; ſo that his year contains 10 thouſand 470 days; and the diurnal velocity of his equatorial parts is greater than the ſwiftneſs with which he moves in his annual Orbit; a ſingular circumſtance, as far as we know. By this prodigious quick Rotation, his equatorial inhabitants are carried 25 thouſand 920 miles every hour (which is 920 miles a hour more than an inhabitant of our Earth's equator moves in twenty-four hours) beſide the 25 thouſand above-mentioned, which is common to all parts of his ſurface, by his annual motion. The number of days in his year.

70. Jupiter is ſurrounded by faint ſubſtances, called *Belts*, in which ſo many changes appear, that they are generally thought to be clouds; for ſome of them have been firſt interrupted and broken, and then have vaniſhed entirely. They have ſometimes been obſerved of different breadths, and afterward have all become nearly of the ſame breadth. Large ſpots have been ſeen in theſe Belts; and when a Belt vaniſhes, the contiguous ſpots diſappear with it. The broken ends of ſome Belts have been generally obſerved to revolve in the ſame time with the ſpots: only thoſe nearer the Equator in ſomewhat leſs time than thoſe near the Poles; perhaps on account of the Sun's greater heat near the Equator, which is parallel to the His Belts and ſpots.

Belts

Belts and courſe of the ſpots. Several large ſpots, which appear round at one time, grow oblong by degrees, and then divide into two or three round ſpots. The periodical time of the ſpots near the Equator is 9 hours 50 minutes, but of theſe near the Poles 9 hours 56 minutes. *See* Dr. SMITH's *Optics*, § 1004, *& ſeq.*

He has no change of ſeaſons;

71. The Axis of Jupiter is ſo nearly perpendicular to his Orbit, that he has no ſenſible change of ſeaſons; which is a great advantage, and wiſely ordered by the Author of Nature. For, if the Axis of this Planet were inclined any conſiderable number of degrees, juſt ſo many degrees round each Pole would in their turn be almoſt ſix of our years together in darkneſs. And, as each degree of a great circle on Jupiter contains 706 of our miles at a mean rate, it is eaſy to judge what vaſt tracks of land would be rendered uninhabitable by any conſiderable inclination of his Axis.

but has four Moons.

72. The Sun appears but $\frac{1}{25}$th part ſo big to Jupiter as to us; and his light and heat are in the ſame ſmall proportion, but compenſated by the quick returns thereof, and by four Moons (ſome bigger and ſome leſs than our Earth) which revolve about him: ſo that there is ſcarce any part of this huge Planet but what is during the whole night enlightened by one or more of theſe Moons, except his Poles, whence only the fartheſt Moons can be ſeen, and where light is not there wanted, becauſe the Sun conſtantly circulates in or near the Horizon, and is very probably kept in view of both Poles by the refraction of Jupiter's Atmoſphere, which, if it be like ours, has certainly refractive power enough for that purpoſe.

Their periods round Jupiter.

73. The Orbits of theſe Moons are repreſented in the Scheme of the Solar Syſtem by four ſmall circles marked 1, 2, 3, 4, on Jupiter's Orbit ♃; but they are drawn fifty times too large in proportion to it. The firſt Moon, or that neareſt to Jupiter, goes round him in 1 day 18 hours and 36

minutes

minutes of our time; and is 229 thouſand miles diſtant from his center: The ſecond performs its revolution in 3 days 13 hours and 15 minutes, at 364 thouſand miles diſtance: The third in 7 days 3 hours and 59 minutes, at the diſtance of 580 thouſand miles: And the fourth or outermoſt, in 16 days 18 hours and 30 minutes, at the diſtance of one million of miles from his center.

Parallax of their Orbits, and diſtances from Jupiter.

74. The Angles under which the Orbits of Jupiter's Moons are ſeen from the Earth, as its mean diſtance from Jupiter, are as follow: The firſt, 3′ 55″; the ſecond, 6′ 14″; the third, 9′ 58″; and the fourth, 17′ 30″. And their diſtances from Jupiter, meaſured by his ſemidiameters, are thus: The firſt, $5\frac{2}{3}$; the ſecond, 9; the third, $14\frac{23}{60}$; and the fourth, $25\frac{18}{60}$*. This Planet, ſeen from its neareſt Moon, appears 1000 times as large as our Moon does to us; waxing and weaning in all her monthly ſhapes, every $42\frac{1}{2}$ hours.

How he appears to his neareſt Moon.

Two grand diſcoveries made by the Eclipſes of Jupiter's Moons.

75. Jupiter's three neareſt Moons fall into his ſhadow, and are eclipſed in every Revolution; but the Orbit of the fourth Moon is ſo much inclined, that it paſſes by its oppoſition to Jupiter, without falling into his ſhadow, two years in every ſix. By theſe Eclipſes, Aſtronomers have not only diſcovered that the Sun's light takes up eight minutes of time in coming to us; but they have alſo determined the longitudes of places on this Earth with greater certainty and facility, than by any other method yet known; as ſhall be explained in the eleventh Chapter.

The great difference between the Equatorial and Polar diameters of Jupiter.

76. The difference between the Equatorial and Polar diameters of Jupiter is 6230 miles; for his equatorial diameter is to his polar, as 13 to 12. So that his Poles are 3115 miles nearer his center than his Equator is. This reſults from his quick motion round his Axis; for the fluids, together

* Cassini *Elemens d'Aſtronomie, Liv.* ix. *Chap.* 3.

with

with the light particles, which they can carry or waſh away with them, recede from the Poles which are at reſt, toward the Equator where the motion is quickeſt, until there be a ſufficient number accumulated to make up the deficiency of gravity loſt by the centrifugal force, which always ariſes from a quick motion round an axis: and when the deficiency of weight or gravity of the particles is made up by a ſufficient accumulation, there is an *equilibrium*, and the equatorial parts riſe no higher. Our Earth being but a very ſmall Planet compared to Jupiter, and its motion on its Axis being much ſlower, it is leſs flattened of courſe: for the difference between its equatorial and polar diameters is only as 230 to 229, namely, 36 miles *.

The difference little in thoſe of our Earth.

Place of his Nodes.

77. Jupiter's Orbit is inclined to the Ecliptic in an angle of 1 degree 20 minutes. His aſcending Node is in the 8th degree of Cancer, and his deſcending Node in the 8th degree of Capricorn.

Saturn.

Fig. I.

78. SATURN, the remoteſt of all the Planets †, is about 780 million of miles from the Sun; and, travelling at the rate of 18 thouſand miles every hour, in the circle marked ♄, performs its annual circuit in 29 years 167 days and 5 hours of our time; which makes only one year to that Planet. Its diameter is 67,000 miles: and therefore it is near 600 times as big as the Earth.

* According to the French meaſures, a Degree of the Meridian at the Equator contains 340606.68 French Feet: and a Degree of the Meridian in Lapland contains 344627.40: ſo that a Degree in Lapland is 4020.72 French Feet (or 4280.02 Engliſh Feet) longer than a Degree at the Equator. The difference is $\frac{81}{100}$ parts of an Engliſh Mile.—Hence, the Earth's Equatorial Diameter contains 39386196 French Feet, or 41926356 Engliſh; and the Polar Diameter 39202920 French Feet, or 41731272 Engliſh. So that the Equatorial Diameter is 195084 Engliſh Feet, or 36.948 Engliſh Miles longer than the Axis.

† The Georgian Planet not diſcovered when this was written.

79. This

79. This Planet is ſurrounded by a thin broad Ring, as an artificial Globe is by a Horizon. The Ring appears double when ſeen through a good teleſcope, and is repreſented by the figure in ſuch an oblique view as it is generally ſeen. It is inclined 30 degrees to the Ecliptic, and is about 21 thouſand miles in breadth; which is equal to its diſtance from Saturn on all ſides. There is reaſon to believe that the Ring turns round its Axis, becauſe, when it is almoſt edge-wiſe to us, it appears ſomewhat thicker on one ſide of the Planet than on the other; and the thickeſt edge has been ſeen on different ſides at different times. But Saturn having no viſible ſpots on his body, whereby to determine the time of his turning round his Axis, the length of his days and nights, and the poſition of his Axis, are unknown to us. PLATE I. Fig. V. His Ring.

80. To Saturn the Sun appears only $\frac{1}{90}$th part ſo big as to us; and the light and heat he receives from the Sun are in the ſame proportion to ours. But to compenſate for the ſmall quantity of ſun-light, he has five Moons, all going round him on the outſide of his Ring, and nearly in the ſame plane with it. The firſt, or neareſt Moon to Saturn, goes round him in 1 day 21 hours 19 minutes; and is 140 thouſand miles from his center: The ſecond, in 2 days 17 hours 40 minutes; at the diſtance of 187 thouſand miles: the third, in 4 days 12 hours 25 minutes; at 263 thouſand miles diſtance: The fourth, in 15 days 22 hours 41 minutes; at the diſtance of 600 thouſand miles: And the fifth, or outermoſt, at one million 800 thouſand miles from Saturn's center, goes round him in 79 days 7 hours 48 minutes. Their Orbits in the Scheme of the Solar Syſtem are repreſented by the five ſmall circles, marked 1. 2. 3. 4. 5. on Saturn's Orbit; but theſe, like the Orbits of the other Satellites, are drawn fifty times too large in proportion to the Orbits of their Primary Planets. His five Moons. Fig. I.

81. The

81. The Sun ſhines almoſt fifteen of our years together on one ſide of Saturn's Ring without ſetting, and as long on the other in its turn. So that the Ring is viſible to the inhabitants of that Planet for almoſt fifteen of our years, and as long inviſible by turns, if its Axis has no inclination to its Ring: but if the Axis of the Planet be inclined to the Ring, ſuppoſe about 30 degrees, the Ring will appear and diſappear once every natural day to all the inhabitants within 30 degrees of the Equator on both ſides, frequently eclipſing the Sun in a Saturnian day. Moreover, if Saturn's Axis be ſo inclined to his Ring, it is perpendicular to his Orbit; and thereby the inconvenience of different ſeaſons to that Planet is avoided. For conſidering the length of Saturn's year, which is almoſt equal to thirty of ours, what a dreadful condition muſt the inhabitants of his Polar regions be in, if they be half that time deprived of the light and heat of the Sun! which is not their caſe alone, if the Axis of the Planet be perpendicular to the Ring, for then the Ring muſt hide the Sun from vaſt tracks of land on each ſide of the Equator for 13 or 14 of our years together, on the ſouth ſide and north ſide by turns, as the Axis inclines to or from the Sun: the reverſe of which inconvenience is another good preſumptive proof of the inclination of Saturn's Axis to its Ring, and alſo of his Axis being perpendicular to his Orbit.

His Axis probably inclined to his Ring.

82. This Ring, ſeen from Saturn, appears like a vaſt luminous Arch in the Heavens, as if it did not belong to the Planet. When we ſee the Ring moſt open, its ſhadow upon the Planet is broadeſt; and from that time the ſhadow grows narrower, as the Ring appears to do to us; until, by Saturn's annual motion, the Sun comes to the Plane of the Ring, or even with its edge; which being then directed toward us, becomes inviſible on account of its thinneſs; as ſhall be explained more largely in the tenth Chapter, and illuſtrated by a figure.

How the Ring appears to Saturn and to us.

The

The Ring diſappears twice in every annual Revolution of Saturn, namely, when he is in the 20th degree both of Piſces and of Virgo. And when Saturn is in the middle between theſe points, or in the 20th degree either of Gemini or of Sagittarius, his Ring appears moſt open to us; and then its longeſt diameter is to its ſhorteſt, as 9 to 4.

In what Signs Saturn appears to loſe his Ring; and in what Signs it appears moſt open to us.

83. To ſuch eyes as ours, unaſſiſted by inſtruments, Jupiter is the only Planet that can be ſeen from Saturn; and Saturn the only Planet that can be ſeen from Jupiter. So that the inhabitants of theſe two Planets muſt either ſee much farther than we do, or have equally good inſtruments to carry their ſight to remote objects, if they know that there is ſuch a body as our Earth in the Univerſe: for the Earth is no bigger ſeen from Jupiter, than his Moons are ſeen from the Earth; and if his large body had not firſt attracted our ſight, and prompted our curioſity to view him with a teleſcope, we ſhould never have known any thing of his Moons; unleſs by chance we had directed the teleſcope toward that ſmall part of the Heavens where they were at the time of obſervation. And the like is true of the Moons of Saturn.

No Planet but Saturn can be ſeen from Jupiter; nor any from Saturn beſide Jupiter.

84. The Orbit of Saturn is $2\frac{1}{2}$ degrees inclined to the Ecliptic, or Orbit of our Earth, and interſects it in the 22d degree of Cancer and of Capricorn; ſo that Saturn's Nodes are only 14 degrees from Jupiter's, § 77 *.

Place of Saturn's Nodes.

85. The

* Since Mr. Ferguſon's death, in 1776, a ſeventh primary Planet belonging to the Solar Syſtem has been diſcovered by Dr. Herſchell, and called by him the *Georgium Sidus*, out of reſpect to his preſent majeſty King George III. This Planet is ſtill higher in the Syſtem than Saturn, being about 1565 million of miles from the Sun; and performs its annual circuit in 83 years 140 days and 8 hours of our time: conſequently its motion, in its Orbit, is at the rate of about 7 thouſand miles in a hour. To a good eye, unaſſiſted by a teleſcope, this Planet appears like a faint Star of the fifth magnitude; and it cannot be readily diſtinguiſhed from a fixed Star

Georgium Sidus.

with

The Sun's light much ſtronger on Jupiter and Saturn than is generally believed.

85. The quantity of light afforded by the Sun to Jupiter, being but $\frac{1}{28}$th part, and to Saturn only $\frac{1}{90}$th part, of what we enjoy; may at firſt thought induce us to believe that theſe two Planets are entirely unfit for rational beings to dwell upon. But that their light is not ſo weak as we imagine, is evident from their brightneſs in the night-time; and alſo from this remarkable Phenomenon, that when the Sun is ſo much eclipſed to us, as to have only the 40th part of his diſc left uncovered by the Moon, the decreaſe of light is not very ſenſible: and juſt at the end of darkneſs in Total Eclipſes, when his weſtern limb begins to be viſible, and ſeems no bigger than a bit of fine ſilver wire, every one is ſurprized at the brightneſs wherewith that ſmall part of him ſhines. The Moon when

with a leſs magnifying power than 200 times. Its apparent diameter ſubtends an angle of no more than 4″ to an obſerver on the Earth; but its real diameter is about 34,000 miles, and, conſequently, it is about 80 times as big as the Earth. Hence we may infer, as the Earth cannot be ſeen under an angle of quite 1″ to the inhabitants of the Georgian Planet, that it has never yet been ſeen by them, unleſs their eyes, or inſtruments, or both, be conſiderably better than ours are.

The Orbit of this Planet is inclined to the Ecliptic in an angle 46′ 26″. Its aſcending Node is in the 13th degree of Gemini, and its deſcending Node in the 13th degree of Sagittarius.

As no ſpots have yet been diſcovered on its ſurface, the poſition of its Axis, and the length of its day and night are not known.

On account of the immenſe diſtance of the Georgian Planet from the ſource of light and heat to all the bodies in our Syſtem, it was highly probable that ſeveral Satellites, or Moons revolved round it: accordingly, the high powers of Dr. Herſchell's teleſcopes have enabled him to diſcover two already; and it is not unlikely but there may be others which he has not yet ſeen. That which is neareſt to the Planet revolves at the diſtance $16\frac{1}{2}$ of the Planet's ſemi-diameters from it, and performs its revolution in 8 days, 17 hours, and 1 minute. The other is about 22 ſemi-diameters of the primary from it, and completes its revolution in 13 days, 11 hours, and 5 minutes. It is remarkable that the Orbits of theſe Satellites are almoſt at right angles to the plane of the Ecliptic.

Full

Full affords travellers light enough to keep them from miſtaking their way; and yet, according to Dr. SMITH*, it is equal to no more than a 90 thouſandth part of the light of the Sun: that is, the Sun's light is 90 thouſand times as ſtrong as the light of the Moon when full. Conſequently, the Sun gives a thouſand times as much light to Saturn as the Full Moon does to us; and above three thouſand times as much to Jupiter. So that theſe two Planets, even without any Moons, would be much more enlightened than we at firſt imagine; and by having ſo many, they may be very comfortable places of reſidence. Their heat, ſo far as it depends on the force of the Sun's rays, is certainly much leſs than ours; to which no doubt the bodies of their inhabitants are as well adapted as ours are to the ſeaſons we enjoy. And if we conſider, that Jupiter never has any winter, even at his Poles, which probably is alſo the caſe with Saturn, the cold cannot be ſo intenſe on theſe two Planets as is generally imagined. Beſides, there may be ſomething in the nature of their mould warmer than in that of our Earth: and we find that all our heat depends not on the rays of the Sun; for if it did, we ſhould always have the ſame months equally hot or cold at their annual returns. But it is far otherwiſe, for *February* is ſometimes warmer than *May*; which muſt be owing to vapours and exhalations from the Earth.

All our heat depends not on the Sun's rays.

86. Every perſon who looks upon, and compares the Syſtems of Moons together, which belong to Jupiter and Saturn, muſt be amazed at the vaſt magnitude of theſe two Planets, and the noble attendance they have in reſpect of our little Earth: and can never bring himſelf to think, that an infinitely wiſe Creator ſhould diſpoſe of all his animals and vegetables here, leaving the other Planets

* Optics, Art. 95.

bare

It is highly probable that all the Planets are inhabited.

bare and deſtitute of rational creatures. To ſuppoſe that he had any view to our benefit, in creating theſe Moons, and giving them their motions round Jupiter and Saturn; to imagine that he intended theſe vaſt Bodies for any advantage to us, when he well knew that they could never be ſeen but by a few Aſtronomers peeping through teleſcopes; and that he gave to the Planets regular returns of days and nights, and different ſeaſons to all where they would be convenient; but of no manner of ſervice to us; except only what immediately regards our own Planet the Earth; to imagine, I ſay, that he did all this on our account, would be charging him impiouſly with having done much in vain: and as abſurd, as to imagine that he has created a little Sun and a Planetary Syſtem within the ſhell of our Earth, and intended them for our uſe. Theſe conſiderations amount to little leſs than a poſitive proof, that all the Planets are inhabited: for if they are not, why all this care in furniſhing them with ſo many Moons, to ſupply thoſe with light which are at the greater diſtances from the Sun? Do we not ſee, that the farther a Planet is from the Sun, the greater Apparatus it has for that purpoſe? ſave only Mars, which being but a ſmall Planet, may have Moons too ſmall to be ſeen by us. We know that the Earth goes round the Sun, and turns round its own Axis, to produce the viciſſitudes of ſummer and winter by the former, and of day and night by the latter motion, for the benefit of its inhabitants. May we not then fairly conclude, by parity of reaſon, that the end and deſign of all the other Planets is the ſame? and is not this agreeable to the beautiful harmony which exiſts throughout the Univerſe? Surely it is: and raiſes in us the moſt magnificent ideas of the SUPREME BEING, who is every where, and at all times preſent; diſplaying his power, wiſdom, and goodneſs among all his creatures! and diſtributing happineſs to innumerable ranks of various beings!

87. In

87. In Fig. II. we have a view of the proportional breadth of the Sun's face or diſc, as ſeen from the different Planets. The Sun is repreſented N° 1, as ſeen from Mercury; N° 2, as ſeen from Venus; N° 3, as ſeen from the Earth; N° 4, as ſeen from Mars; N° 5, as ſeen from Jupiter; and N° 6, as ſeen from Saturn. PLATE I. Fig. II. How the Sun appears to the different Planets.

Let the circle *B* be the Sun as ſeen from any Planet at a given diſtance; to another Planet, at double that diſtance, the Sun will appear juſt of half that breadth, as *A*; which contains only one fourth part of the area or ſurface of *B*. For all circles, as well as ſquare ſurfaces, are to one another as the ſquares of their diameters. Thus, the ſquare *A* is juſt half as broad as the ſquare *B*; and yet it is plain to ſight, that *B* contains four times as much ſurface as *A*. Hence, by comparing the diameters of the above Circles (Fig. II.) together, it will be found, that in round numbers, the Sun appears 7 times larger to Mercury than to us, 90 times larger to us than to Saturn, and 630 times as large to Mercury as to Saturn. Fig. III. Fig. IV.

88. In Fig. V. we have a view of the bulks of the Planets in proportion to each other, and to a ſuppoſed globe of two feet diameter for the Sun. The Earth is 27 times as big as Mercury, very little bigger than Venus, 5 times as big as Mars; but Jupiter is 1049 times as big as the Earth, Saturn 586 times as big, excluſive of his Ring; and the Sun is 877 thouſand 650 times as big as the Earth. If the Planets in this Figure were ſet at their due diſtances from a Sun of two feet diameter, according to their proportional bulks, as in our Syſtem, Mercury would be 28 yards from the Sun's center; Venus 51 yards 1 foot; the Earth 70 yards 2 feet; Mars 107 yards 2 feet; Jupiter 370 yards 2 feet; and Saturn 760 yards 2 feet. The Comet of the year 1680, at its greateſt diſtance, 10 thouſand 760 yards. In this proportion, the Moon's diſtance from the center of the Earth would be only $7\frac{1}{2}$ inches. Fig. V. Proportional bulks and diſtances of the Planets.

D

PLATE I. An idea of their diſtances.

89. To aſſiſt the imagination in forming an idea of the vaſt diſtances of the Sun, Planets, and Stars, let us ſuppoſe, that a body projected from the Sun ſhould continue to fly with the ſwiftneſs of a cannon-ball, *i. e.* 480 miles every hour; this body would reach the Orbit of Mercury, in 7 years 221 days; of Venus, in 14 years 8 days; of the Earth, in 19 years 91 days; of Mars, in 29 years 85 days; of Jupiter, in 100 years 280 days; of Saturn, in 184 years 240 days; to the Comet of 1680, at its greateſt diſtance from the Sun, in 2660 years; and to the neareſt fixed Stars in about 7 million 600 thouſand years.

Why the Planets appear bigger and leſs at different times.

90. As the Earth is not in the center of the Orbits in which the Planets move, they come nearer to it and go farther from it, at different times; on which account they appear bigger and leſs by turns. Hence, the apparent magnitudes of the Planets are not always a certain rule to know them by.

21. Under Fig. III. are the names and characters of the twelve ſigns of the Zodiac, which the Reader ſhould be perfectly well acquainted with; ſo as to know the characters without ſeeing the names. Each ſign contains 30 degrees, as in the Circle bounding the Solar Syſtem; to which the characters of the ſigns are ſet in their proper places.

Fig. I.

The Comets.

92. The Comets are ſolid opaque bodies, with long tranſparent trains or tails, iſſuing from that ſide which is turned away from the Sun. They move about the Sun in very eccentric ellipſes; and are of a much greater denſity than the Earth; for ſome of them are heated in every period to ſuch a degree, as would vitrify or diſſipate any ſubſtance known to us. Sir Isaac Newton computed the heat of the Comet which appeared in the year 1680, when neareſt the Sun, to be 2000 times hotter than red-hot iron, and that being thus heated, it muſt retain its heat until it comes round again, although its Period ſhould be more than twenty thouſand

thouſand years; and it is computed to be only 575. The method of computing the heat of bodies, keeping at any known diſtance from the Sun, ſo far as their heat depends on the force of the Sun's rays, is very eaſy; and ſhall be explained in the eighth Chapter. PLATE I.

93. Part of the Paths of three Comets are delineated in the Scheme of the Solar Syſtem, and the years marked in which they made their appearance. There are, at leaſt, 21 Comets belonging to our Syſtem, moving in all ſorts of directions; and all thoſe which have been obſerved, have moved through the ethereal Regions and the Orbits of the Planets, without ſuffering the leaſt ſenſible reſiſtance in their motions; which plainly proves that the Planets do not move in ſolid Orbs. Of all the Comets, the Periods of the above mentioned three only are known with any degree of certainty. The firſt of theſe Comets appeared in the years 1531, 1607, and 1682; and is expected to appear again in the year 1758, and every 75th year afterward. The ſecond of them appeared in 1532 and 1661, and may be expected to return in 1789, and every 129th year afterward. The third, having laſt appeared in 1680, and its Period being no leſs than 575 years, cannot return until the year 2225. This Comet, at its greateſt diſtance, is about eleven thouſand two hundred million of miles from the Sun; and at its leaſt diſtance from the Sun's center, which is 49,000 miles, is within leſs than a third part of the Sun's ſemidiameter from his ſurface. In that part of its Orbit which is neareſt the Sun, it flies with the amazing ſwiftneſs of 880,000 miles in a hour; and the Sun, as ſeen from it, appears a hundred degrees in breadth; conſequently 40 thouſand times as large as he appears to us. The aſtoniſhing length that this Comet runs out into empty ſpace, ſuggeſts to our minds an idea of the vaſt diſtance between the Sun and the neareſt fixed Stars; of whoſe Attractions all the Comets muſt

Fig. I.

They prove that the Orbits of the Planets are not ſolid.

The Periods only of three are known.

They prove the Stars to be at immenſe diſtances.

keep clear, to return periodically, and go round the Sun; and it ſhews us alſo, that the neareſt Stars, which are probably thoſe that ſeem the largeſt, are as big as our Sun, and of the ſame nature with him; otherwiſe, they could not appear ſo large and bright to us as they do at ſuch an immenſe diſtance.

Inferences drawn from the above phenomena.

94. The extreme heat, the denſe atmoſphere, the groſs vapours, the chaotic ſtate of the Comets, ſeem at firſt ſight to indicate them altogether unfit for the purpoſes of animal life, and a moſt miſerable habitation for rational beings; and therefore ſome* are of opinion that they are ſo many hells for tormenting the damned with perpetual viciſſitudes of heat and cold. But when we conſider, on the other hand, the infinite power and goodneſs of the Deity; the latter inclining, the former enabling him to make creatures ſuited to all ſtates and circumſtances; that matter exiſts only for the ſake of intelligent beings; and that wherever we find it, we always find it pregnant with life, or neceſſarily ſubſervient thereto; the numberleſs ſpecies, the aſtoniſhing diverſity of animals in earth, air, water, and even on other animals; every blade of graſs, every tender leaf, every natural fluid, ſwarming with life; and every one of theſe enjoying ſuch gratifications as the nature and ſtate of each requires: when we reflect moreover that ſome centuries ago, till experience undeceived us, a great part of the Earth was adjudged uninhabitable; the Torrid Zone, by reaſon of exceſſive heat, and the two Frigid Zones becauſe of their intolerable cold; it ſeems highly probable, that ſuch numerous and large maſſes of durable matter as the Comets are, however unlike they be to our Earth, are not deſtitute of beings capable of contemplating with wonder, and acknowledging with gratitude, the wiſdom, ſymmetry and beauty of the Creation;

* Mr. Whiston, in his Aſtronomical Principles of Religion.

which is more plainly to be obferved in their extenfive Tour through the Heavens, than in our more confined Circuit. If farther conjecture is permitted, may we not fuppofe them inftrumental in recruiting the expended fuel of the Sun; and fupplying the exhaufted moifture of the Planets? However difficult it may be, circumftanced as we are, to find out their particular deftination, this is an undoubted truth, that wherever the Deity exerts his power, there he alfo manifefts his wifdom and goodnefs.

95. THE SOLAR SYSTEM, here defcribed, is not a late invention; for it was known and taught by the wife *Samian* philofopher PYTHAGORAS, and others among the Ancients: but in latter times was loft, till the 15th century, when it was again reftored by the famous *Polifh* philofopher, NICHOLAUS COPERNICUS, who was born at *Thorn* in the year 1473. In this, he was followed by the greateft mathematicians and philofophers that have fince lived; as KEPLER, GALILEO, DESCARTES, GASSENDUS, and Sir ISAAC NEWTON; the laft of whom has eftablifhed this Syftem on fuch an everlafting foundation of mathematical and phyfical demonftration, as can never be fhaken: and none who underftand him can hefitate about it.

This Syftem very ancient, and demonftrable.

96. In the *Ptolomean Syftem*, the Earth was fuppofed to be fixed in the Center of the Univerfe; and that the Moon, Mercury, Venus, the Sun, Mars, Jupiter, and Saturn, moved round the Earth: above the Planets, this Hypothefis placed the Firmament of Stars, and then the two Chryftalline Spheres; all which were included in and received motion from the *Primum Mobile*, which conftantly revolved about the Earth in 24 hours from Eaft to Weft. But as this rude fcheme was found incapable of ftanding the teft of art and obfervation, it was foon rejected by all true philofophers; notwithftanding the oppofition and violence of blind and zealous bigots.

The Ptolomean Syftem abfurd.

97. The

The Tychonic Syſtem, partly true, and partly falſe.

97. The *Tychonic Syſtem* ſucceeded the *Ptolomean*, but was never ſo generally received. In this the Earth was ſuppoſed to ſtand ſtill in the Center of the Univerſe or Firmament of Stars, and the Sun to revolve about it every 24 hours; the Planets, Mercury, Venus, Mars, Jupiter, and Saturn, going round the Sun in the times already mentioned. But ſome of TYCHO's diſciples ſuppoſed the Earth to have a diurnal motion round its Axis, and the Sun with all the above Planets to go round the Earth in a year; the Planets moving round the Sun in the foreſaid times. This hypotheſis, being partly true and partly falſe, was embraced by few; and ſoon gave way to the only true and rational Syſtem, reſtored by COPERNICUS, and demonſtrated by Sir ISAAC NEWTON.

98. To bring the foregoing particulars into one point of view, with ſeveral others which follow, concerning the periods, Diſtances, Bulks, &c. of the Planets, the following Table is inſerted.

A TABLE

A Table of the Periods, Revolutions, Magnitudes, &c. of the Planets, on a supposition of the Sun's Parallax being 10″.

For their nearly true Distances from the Sun, as determined from Observations of the Transit of Venus, in the year 1761, *see* § 194.

Sun and Planets.	Annual period round the Sun.	Diurnal rotation on its Axis.	Diameter in English miles.	Mean diam. as seen fr. the Sun.	Mean distance from the Sun in English miles.	Eccentricity of its Orbit in miles.	Axis inclined to its Orbit.	Orbit inclined to the Ecliptic	Place of its Aphelion.	Place of its Ascending Node.	Proportion of Diameters.	Proportion of Bulk.	Prop. of Gravity on the surface.	Proportion of Density.
Sun	—	25d. 6h.	763000	—	—	—	8° 0′	—	—	—	10000	877650	24	$25\frac{1}{2}$
Mercury	87d. 23h.	Unknown.	2600	20″	32,000,000	6,720,000	Unkn	6° 54′	♐ 13° 8′	♉ 14 43′	$34\frac{1}{10}$	$\frac{1}{27}$	Unkn.	Unkn.
Venus	224d. 17h.	24d. 8h.	7906	30″	59,000,000	413,000	75° 0′	3° 20′	♒ 4° 20′	♊ 13° 59′	$103\frac{1}{2}$	1	Unkn.	Unkn.
Earth	365d. 6h.	1d. 0h.	7970	21″	82,000,000	1,377,000	23° 29′	—	♑ 8° 1′	—	$104\frac{1}{2}$	1	1	100
Moon	365d. 6h.	29d. $12\frac{3}{4}$h.	2180	6″	82,000,000	13,000	2° 10′	5° 18′	—	Variable.	$28\frac{1}{2}$	$\frac{1}{50}$	$\frac{34}{100}$	$123\frac{1}{2}$
Mars	686d. 23h.	24h. 40m.	4444	11″	125,000,000	11,439,000	0° 0′	1° 52′	♍ 0° 32′	♉ 17° 17′	$58\frac{1}{7}$	$\frac{1}{5}$	Unkn.	Unkn.
Jupiter	4332d. 12h.	9h. 56m.	81000	37″	426,000,000	20,352,000	0° 0′	1° 20′	♎ 9° 10′	♋ 7° 29′	$1061\frac{1}{3}$	1049	2	19
Saturn	10759d. 7h.	Unknown.	67000	16″	780,000,000	42,735,000	Unkn.	2° 30′	♐ 27° 50′	♋ 21° 13′	$878\frac{1}{9}$	586	$1\frac{1}{2}$	15
Georgian	30456d. 2h.	Unknown.	35000	0 9″	1565,000,000	74,404,000	Unkn.	0° 46′	♓ 13° 12′	♊ 12° 49′	$448\frac{3}{7}$	$79\frac{2}{3}$	$1\frac{1}{7}$	22

Sun and Planets.	Proportion of Light & Heat	Propor. quantity of Matter.	Hourly motion in its Orbit.	Hourly motion of its Equator.	Square miles in surface.	Cubic miles in solidity.	Projectile force being destroyed would fall to the Sun in	
							days	hours
Sun	4500	227500	—	3818	1,828,911,000,000	232,577,115,137,000,000		
Mercury	$6\frac{1}{2}$	Unkn.	95000	Unkn.	21,236,800	9,195,534,500	15	13
Venus	$1\frac{3}{4}$	Unkn.	69000	43	691,361,300	258,507,832,100	39	17
Earth	1	1	58000	1042	199,859,860	265,404,598,080	64	10
Moon	1 ±	$\frac{1}{40}$	2290	$9\frac{1}{2}$	14,898,750	5,408,246,000	64	10
Mars	$\frac{3}{7}$	Unkn.	47000	556	62,038,240	45,969,335,840	121	0
Jupiter	$\frac{1}{28}$	220	25000	25920	20 603,970,000	278,153,595,000,000	290	0
Saturn	$\frac{1}{90}$	94	18000	Unkn	14,102,562,000	155,128,182,000,000	767	0
Georgian	$\frac{1}{363}$	13	7000	Unkn	3,678,183,000	20,976,679,225 000	1307	0

Moons. No	Periods round Jupiter. D.	H.	M.	Periods round Saturn. D.	H.	M.	Periods round the Georgian. D.	H.	M.
1	1	18	36	1	21	19	8	17	1
2	3	13	15	2	17	40	13	11	5
3	7	3	59	4	12	25			
4	16	18	50	15	22	41			
5				79	7	48			

The Moon belonging to the Earth goes round its Orbit in 27 days 7 hours 43 minutes, and if the projectile force was destroyed would fall to the Earth in 4 days 21 hours.

CHAP. III.

The COPERNICAN SYSTEM *demonstrated to be true.*

Of matter and motion.

99. MATTER is of itself inactive, and indifferent to motion or rest. A body at rest can never put itself in motion; a body in motion can never stop or move slower of itself. Hence, when we see a body in motion, we conclude some other substance must have given it that motion; when we see a body fall from motion to rest, we conclude some other body or cause stopt it.

100. All motion is naturally rectilineal. A bullet thrown by the hand, or discharged from a cannon, would continue to move in the same direction it received at first, if no other power diverted its course. Therefore, when we see a body moving in a curve of whatever kind, we conclude it must be acted upon by two powers at least: one to put it in motion, and another drawing it off from the rectilineal course which it would otherwise have continued to move in.

Gravity demonstrable.

101. The power by which bodies fall toward the Earth, is called *Gravity* or *Attraction*. By this power in the Earth it is, that all bodies, on whatever side, fall in lines perpendicular to its surface. On opposite parts of the Earth bodies fall in opposite directions, all toward the center, where the whole force of gravity is, as it were, accumulated. By this power constantly acting on bodies near the Earth, they are kept from leaving it altogether; and those on its surface, are kept thereto on all sides, so that they cannot fall from it. Bodies thrown with any obliquity are drawn by this power from a straight line into a curve, until they fall to the ground: the greater the force by which they are thrown, the greater is the distance they are carried before they fall. If we suppose a body carried several

ſeveral miles above the Earth, and there projected in a horizontal direction with ſo great a velocity that it would move more than a ſemidiameter of the Earth in the time it would take to fall to the Earth by gravity; in that caſe, if there were no reſiſting medium in the way, the body would not fall to the Earth at all, but continue to circulate round the Earth, keeping always the ſame path, and returning to the point from whence it was projected with the ſame velocity as at firſt.

102. We find the Moon moves round the Earth in an Orbit nearly circular. The Moon therefore muſt be acted on by two powers or forces; one which would cauſe her to move in a right line, another bending her motion from that line into a curve. This attractive power muſt be ſeated in the Earth, for there is no other body within the Moon's Orbit to draw her. The attractive power of the Earth therefore extends to the Moon; and in combination with her projectile force, cauſes her to move round the Earth in the ſame manner as the circulating body above ſuppoſed. Projectile force demonſtrable.

103. The Moons of Jupiter and Saturn are obſerved to move round their primary Planets: therefore there is an attractive power in theſe Planets. All the Planets move round the Sun, and reſpect it for their center of motion: therefore the Sun muſt be endowed with an attracting power, as well as the Earth and Planets. The like may be proved of the Comets. So that all the bodies or matter of the Solar Syſtem, are poſſeſſed of this power; and perhaps ſo is all matter whatever. The Sun and Planets attract each other.

104. As the Sun attracts the Planets with their Satellites, and the Earth the Moon, ſo the Planets and Satellites re-attract the Sun, and the Moon the Earth; action and re-action being always equal. This is alſo confirmed by obſervation; for the Moon raiſes tides in the ocean, and the Satellites and Planets diſturb one another's motions.

105. Every

105. Every particle of matter being poſſeſſed of an attracting power, the effect of the whole muſt be in proportion to the number of attracting particles: that is, to the quantity of matter in the body. This is demonſtrated from experiments on pendulums: for if they are of equal lengths, whatever their weights be, they always vibrate in equal times. Now, if one be double the weight of another, the force of gravity or attraction muſt be double to make it oſcillate with the ſame celerity: if one is thrice the weight or quantity of matter of another, it requires thrice the force of gravity to make it move with the ſame celerity. Hence it is certain, that the power of gravity is always proportional to the quantity of matter in bodies, whatever their bulks or figures are.

106. Gravity alſo, like all other virtues or emanations, either drawing or impelling a body toward a center, decreaſes as the ſquare of the diſtance increaſes: that is, a body at twice the diſtance attracts another with only a fourth part of the force; at four times the diſtance, with a ſixteenth part of the force. This too is confirmed from obſervation, by comparing the diſtance which the Moon falls in a minute from a right line touching her Orbit, with the ſpace which bodies near the Earth fall in the ſame time: and alſo by comparing the forces which retain Jupiter's Moons in their Orbits. This will be more fully explained in the ſeventh Chapter.

G avitation and projection exemplified.

107. The mutual attraction of bodies may be exemplified by a boat and a ſhip on the water, tied by a rope. Let a man either in a ſhip or boat pull the rope (it is the ſame in effect at which end he pulls, for the rope will be equally ſtretched throughout) the ſhip and boat will be drawn toward one another; but with this difference, that the boat will move as much faſter than the ſhip, as the ſhip is heavier than the boat. Suppoſe the boat as heavy as the ſhip, and they will draw one

 another

another equally (ſetting aſide the greater reſiſtance of the Water on the bigger body) and meet in the middle of the firſt diſtance between them. If the ſhip is a thouſand or ten thouſand times heavier than the boat, the boat will be drawn a thouſand or ten thouſand times faſter than the ſhip; and meet proportionably nearer the place from which the ſhip ſet out. Now, while one man pulls the rope, endeavouring to bring the ſhip and boat together, let another man, in the boat, endeavour to row it off ſideway, or at right angles to the rope; and the former, inſtead of being able to draw the boat to the ſhip, will find it enough for him to keep the boat from going further off; while the latter, endeavouring to row off the boat in a ſtraight line, will, by means of the other's pulling it toward the ſhip, row the boat round the ſhip at the rope's length from her. Here the power employed to draw the ſhip and boat to one another repreſents the mutual attraction of the Sun and Planets by which the Planets would fall freely toward the Sun with a quick motion; and would alſo in falling attract the Sun toward them. And the power employed to row off the boat repreſents the projectile force impreſſed on the Planets at right angles, or nearly ſo, to the Sun's attraction; by which means the Planets move round the Sun, and are kept from falling to it. On the other hand, if it be attempted to make a heavy ſhip go round a light boat, they will meet ſooner than the ſhip can get round; or the ſhip will drag the boat after it.

108. Let the above principles be applied to the Sun and Earth; and they will evince, beyond a poſſibility of doubt, that the Sun, not the Earth, is the center of the Syſtem; and that the Earth moves round the Sun as the other Planets do.

For, if the Sun moves about the Earth, the Earth's attractive power muſt draw the Sun toward it from the line of projection, ſo as to bend its motion

motion into a curve. But the Sun being at leaſt 227 thouſand times as heavy as the Earth, by being ſo much weightier as its quantity of matter is greater, it muſt move 227 thouſand times as ſlowly toward the Earth, as the Earth does toward the Sun; and conſequently the Earth would fall to the Sun in a ſhort time, if it had not a very ſtrong projectile motion to carry it off. The Earth therefore, as well as every other Planet in the Syſtem, muſt have a rectilineal impulſe, to prevent its falling to the Sun. To ſay, that gravitation retains all the other Planets in their Orbits without affecting the Earth, which is placed between the Orbits of Mars and Venus, is as abſurd as to ſuppoſe that ſix cannon bullets might be projected upward to different heights in the Air, and that five of them ſhould fall down to the ground; but the ſixth, which is neither the higheſt nor the loweſt, ſhould remain ſuſpended in the Air without falling, and the earth move round about it.

The abſurdity of ſuppoſing the Earth at reſt.

109. There is no ſuch thing in nature as a heavy body moving round a light one as its center of motion. A pebble faſtened to a mill-ſtone by a ſtring, may by an eaſy impulſe be made to circulate round the mill-ſtone: but no impulſe can make a mill-ſtone circulate round a looſe pebble; for the mill-ſtone would go off, and carry the pebble along with it.

110. The Sun is ſo immenſely bigger and heavier than the Earth *, that if he was moved out of his place, not only the Earth, but all the other Planets, if they were united into one maſs, would be carried along with the Sun, as the pebble would be with the mill-ſtone.

111. By conſidering the law of gravitation, which takes place throughout the Solar Syſtem, in another light, it will be evident that the Earth moves round the Sun in a year; and not the Sun round the Earth. It has been ſhewn (§ 106) that

* As will be demonſtrated in the Ninth Chapter.

the power of gravity decreafes as the fquare of the diftance increafes; and from this it follows with mathematical certainty, that when two or more bodies move round another as their center of motion, the fquares of their periodic times will be to one another in the fame proportion as the cubes of their diftances from the central body. This holds precifely with regard to the Planets round the Sun, and the Satellites round the Planets; the relative diftances of all which are well known. But, if we fuppofe the Sun to move round the Earth, and compare its period with the Moon's by the above rule, it will be found that the Sun would take no lefs than 173,510 days to move round the Earth, in which cafe our year would be 475 times as long as it now is. To this we may add, that the afpects of increafe and decreafe of the Planets, the times of their feeming to ftand ftill, and to move direct and retrograde, anfwer precifely to the Earth's motion; but not at all to the Sun's, without introducing the moft abfurd and monftrous fuppofitions, which would deftroy all harmony, order, and fimplicity in the Syftem. Moreover, if the Earth be fuppofed to ftand ftill, and the Stars to revolve in free fpaces about the Earth in 24 hours, it is certain that the forces by which the Stars revolve in their Orbits are not directed to the Earth, but to the centers of the feveral Orbits; that is, of the feveral parallel Circles which the Stars on different fides of the Equator defcribe every day; and the like inferences may be drawn from the fuppofed diurnal motion of the Planets, fince they are never in the Equinoctial but twice in their courfes with regard to the ftarry Heavens. But, that forces fhould be directed to no central body, on which they phyfically depend, but to innumerable imaginary points in the Axis of the Earth produced to the Poles of the Heavens, is a hypothefis too abfurd to be allowed of by any rational creature. And it is ftill more ab-

The harmony of the celeftial motions.

The abfurdity of fuppofing the Stars and Planets to move round the Earth.

furd

surd to imagine that these forces should increase exactly in proportion to the distances from this Axis; for that is an indication of an increase to infinity; whereas the force of attraction is found to decrease in receding from the fountain from whence it flows. But, the farther any Star is from the quiescent Pole, the greater must be the Orbit which it describes; and yet it appears to go round in the same time as the nearest Star to the Pole does. And if we take into consideration the two-fold motion observed in the Stars, one diurnal round the Axis of the Earth in 24 hours, and the other round the Axis of the Ecliptic in 25920 years, § 251, it would require an explication of such a perplexed composition of forces, as could by no means be reconciled with any physical Theory.

Objections against the Earth's motion answered.

112. There is but one objection of any weight that can be made against the Earth's motion round the Sun, which is, that in opposite points of the Earth's Orbit, its Axis, which always keeps a parallel direction, would point to different fixed Stars; which is not found to be fact. But this objection is easily removed, by considering the immense distance of the Stars in respect of the diameter of the Earth's Orbit; the latter being no more than a point when compared to the former. If we lay a ruler on the side of a table, and along the edge of the ruler view the top of a spire at ten miles distance, then lay the ruler on the opposite side of the table in a parallel situation to what it had before, and the spire will still appear along the edge of the ruler; because our eyes, even when assisted by the best instruments, are incapable of distinguishing so small a change at so great a distance.

113. Dr. Bradley found by a long series of the most accurate observations, that there is a small apparent motion of the fixed Stars, occasioned by the aberration of their light, and so exactly answering to an

an annual motion of the Earth, as evinces the ſame, even to a mathematical demonſtration. Thoſe who are qualified to read the Doctor's modeſt Account of this great diſcovery, may conſult the *Philoſophical Tranſactions*, N° 406. Or they may find it treated of at large by Drs. SMITH *, LONG †, DESAGULIERS ‡, RUTHERFURTH ‖, Mr. MACLAURIN, Mr. SIMPSON ¶, and M. DE LA CAILLE **.

Why the Sun appears to change his place.

114. It is true that the Sun ſeems to change his place daily, ſo as to make a tour round the ſtarry Heavens in a year. But whether the Sun or Earth moves, this appearance will be the ſame; for, when the Earth is in any part of the Heavens, the Sun will appear in the oppoſite. And therefore this appearance can be no objection againſt the motion of the Earth.

115. It is well known to every perſon who has ſailed on ſmooth water, or been carried by a ſtream in a calm, that, however faſt the veſſel goes, he does not feel its progreſſive motion. The motion of the Earth is incomparably more ſmooth and uniform than that of a ſhip, or any machine made and moved by human art: and therefore it is not to be imagined that we can feel its motion.

The Earth's motion on its Axis demonſtrated.

116. We find that the Sun, and thoſe Planets on which there are viſible ſpots, turn round their Axes: for the ſpots move regularly over their Diſcs ††. From hence we may reaſonably conclude, that the other Planets, on which we ſee no ſpots, and the Earth, which is likewiſe a Planet, have ſuch rotations. But being incapable of leaving the Earth, and viewing it at a diſtance, and its rotation being ſmooth and uniform, we can neither

* Optics, B. I. § 1178. † Aſtronomy, B. II. § 838.
‡ Philoſophy, Vol. I. p. 401. ‖ Account of Sir Iſaac Newton's *Philoſophical Diſcoveries*, B. III. c. 2. § 3.
¶ Mathemat. Eſſays, p. 1. ** *Elemens d'Aſtronomie*, § 381.
†† The face of the Sun, Moon, or any Planet, as it appears to the eye, is called its Diſc.

ſee it move on its Axis as we do the Planets, nor feel ourſelves affected by its motion. Yet there is one effect of ſuch a motion, which will enable us to judge with certainty whether the Earth revolves on its Axis or not. All Globes which do not turn round their Axes will be perfect ſpheres, on account of the equality of the weight of bodies on their ſurfaces; eſpecially of the fluid parts. But all Globes which turn on their Axes will be oblate ſpheriods; that is, their ſurfaces will be higher or farther from the center in the equatorial than in the polar Regions; for, as the equatorial parts move quickeſt, they will recede fartheſt from the Axis of motion, and enlarge the equatorial diameter. That our Earth is really of this figure, is demonſtrable from the unequal vibrations of a pendulum, and the unequal lengths of degrees in different latitudes. Since then the Earth is higher at the Equator than at the Poles, the ſea, which naturally runs downward, or toward the places which are neareſt the center, would run toward the polar Regions, and leave the equatorial parts dry, if the centrifugal force of theſe parts by which the waters were carried thither did not keep them from returning. The Earth's equatorial diameter is 36 miles longer than its Axis.

All bodies heavier at the Poles than they would be at the Equator.

117. Bodies near the Poles are heavier than thoſe toward the Equator, becauſe they are nearer the Earth's center, where the whole force of the Earth's attraction is accumulated. They are alſo heavier, becauſe their centrifugal force is leſs, on account of their diurnal motion being ſlower. For both theſe reaſons, bodies carried from the Poles toward the Equator, gradually loſe of their weight. Experiments prove that a pendulum, which vibrates ſeconds near the Poles, vibrates ſlower near the Equator, which ſhews, that it is lighter or leſs attracted there. To make it oſcillate in the ſame time, it is found neceſſary to diminiſh its length. By comparing the different lengths of pendulums ſwinging

ſwinging ſeconds at the Equator and at *London*, it is found that a pendulum muſt be $2\frac{162}{1000}$ lines ſhorter at the Equator than at the Poles. A line is a twelfth part of an inch.

118. If the Earth turned round its Axis in 84 minutes 43 ſeconds, the centrifugal force would be equal to the power of gravity at the Equator; and all bodies there would entirely loſe their weight. If the Earth revolved quicker, they would all fly off, and leave it.

How they might loſe all their weight.

119. A perſon on the Earth can no more be ſenſible of its undiſturbed motion on its Axis, than one in the cabin of a ſhip on ſmooth water can be ſenſible of the ſhip's motion when it turns gently and uniformly round. It is therefore no argument againſt the Earth's diurnal motion, that we do not feel it: nor is the apparent revolutions of the celeſtial bodies every day a proof of the reality of theſe motions; for whether we or they revolve, the appearance is the very ſame. A perſon looking through the cabin-windows of a ſhip as ſtrongly fancies the objects on land to go round when the ſhip turns, as if they were actually in motion.

The Earth's motion cannot be felt.

120. If we could tranſlate ourſelves from Planet to Planet, we ſhould ſtill find that the Stars would appear of the ſame magnitudes, and at the ſame diſtances from each other, as they do to us here: becauſe the width of the remoteſt Planet's Orbit bears no ſenſible proportion to the diſtance of the Stars. But then, the Heavens would ſeem to revolve about very different Axes; and conſequently, thoſe quieſcent points, which are our Poles in the Heavens, would ſeem to revolve about other points, which, though apparently in motion as ſeen from the Earth, would be at reſt as ſeen from any other Planet. Thus the Axis of Venus, which lies almoſt at right Angles to the Axis of the Earth, would have its motionleſs Poles in two oppoſite points of the Heavens lying almoſt in our Equinoctial,

To the different Planets the Heavens appear to turn round on different Axes.

noctial, where the motion appears quickeſt, becauſe it is ſeemingly performed in the greateſt Circle. And the very Poles, which are at reſt to us, have the quickeſt motion of all as ſeen from Venus. To Mars and Jupiter the Heavens appear to turn round with very different velocities on the ſame Axis, whoſe Poles are about 23½ degrees from ours. Were we on Jupiter, we ſhould be at firſt amazed at the rapid motion of the Heavens; the Sun and Stars going round in 9 hours 56 minutes. Could we go from thence to Venus, we ſhould be as much ſurpriſed at the ſlowneſs of the heavenly motions; the Sun going but once round in 584 hours, and the Stars in 540. And could we go from Venus to the Moon, we ſhould ſee the Heavens turn round with a yet ſlower motion; the Sun in 708 hours, the Stars in 655. As it is impoſſible theſe various circumvolutions in ſuch different times, and on ſuch different Axes, can be real, ſo it is unreaſonable to ſuppoſe the Heavens to revolve about our Earth more than it does about any other Planet. When we reflect on the vaſt diſtance of the fixed Stars, to which 162,000,000 of miles, the diameter of the Earth's Orbit, is but a point, we are filled with amazement at the immenſity of their diſtance. But if we try to frame an idea of the extreme rapidity with which the Stars muſt move, if they move round the Earth in 24 hours, the thought becomes ſo much too big for our imagination, that we can no more conceive it than we do infinity or eternity. If the Sun was to go round the Earth in 24 hours, he muſt travel upward of 300,000 miles in a minute: but the Stars being at leaſt 400,000 times as far from the Sun as the Sun is from us, thoſe about the Equator muſt move 400,000 times as quick. And all this to ſerve no other purpoſe than what can be as fully and much more ſimply obtained by the Earth's turning round eaſtward, as on an Axis, every 24 hours, cauſing thereby an apparent

diurnal

diurnal motion of the Sun weſtward, and bringing about the alternate returns of day and night.

121. As to the common objections againſt the Earth's motion on its Axis, they are all eaſily anſwered and ſet aſide. That it may turn without being ſeen or felt by us to do ſo, has been already ſhewn, § 119. But ſome are apt to imagine that if the Earth turns eaſtward (as it certainly does, if it turns at all) a ball fired perpendicularly upward in the air muſt fall conſiderably weſtward of the place it was projected from. The objection, which at firſt ſeems to have ſome weight, will be found to have none at all, when we conſider that the gun and ball partake of the Earth's motion; and therefore the ball being carried forward with the air as quick as the Earth and air turn, muſt fall down on the ſame place. A ſtone let fall from the top of a main-maſt, if it meets with no obſtacle, falls on the deck as near the foot of the maſt when the ſhip ſails as when it does not. If an inverted bottle, full of liquor, be hung up to the cieling of the cabin, and a ſmall hole be made in the cork to let the liquor drop through on the floor, the drops will fall juſt as far forward on the floor when the ſhip ſails as when it is at reſt. And gnats or flies can as eaſily dance among one another in a moving cabin as in a fixed chamber. As for thoſe ſcripture expreſſions which ſeem to contradict the Earth's motion, the following reply may be made to them all: It is plain from many inſtances, that the Scriptures were never intended to inſtruct us in Philoſophy or Aſtronomy; and therefore, on thoſe ſubjects, expreſſions are not always to be taken in the literal ſenſe; but for the moſt part as accommodated to the common apprehenſions of mankind. Men of ſenſe in all ages, when not treating of the ſciences purpoſely, have followed this method: and it would be in vain to follow any other in addreſſing ourſelves to the vulgar, or bulk of any

Objections againſt the Earth's diurnal motion anſwered.

community. *Moſes* calls the Moon A GREAT LUMINARY (as it is in the Hebrew) as well as the Sun: but the Moon is known to be an opaque body, and the ſmalleſt that Aſtronomers have obſerved in the Heavens; and ſhines upon us not by any inherent light of its own, but by reflecting the light of the Sun. *Moſes* might know this, but had he told the *Iſraelites* ſo, they would have ſtared at him; and conſidered him rather as a madman, than as a perſon commiſſioned by the Almighty to be their leader.

CHAP. IV.

The Phenomena of the Heavens as ſeen from different Parts of the Earth.

We are kept to the Earth by gravity.

122. WE are kept to the Earth's ſurface on all ſides by the power of its central attraction; which, laying hold of all bodies according to their denſities or quantities of matter, without regard to their bulks, conſtitutes what we call their *weight*. And having the ſky over our heads, go where we will, and our feet toward the center of the Earth, we call it *up* over our heads, and *down* under our feet: although the ſame right line which is *down* to us, if continued through and beyond the oppoſite ſide of the Earth, would be *up* to the inhabitants on the oppoſite ſide. For, the inhabitants *n*, *i*, *e*, *m*, *s*, *o*, *q*, *l*, ſtand with their feet toward the Earth's center *C*; and have the ſame figure of ſky *N*, *I*, *E*, *M*, *S*, *O*, *Q*, *L*, over their heads. Therefore, the point *S* is as directly upward to the inhabitant *s* on the South Pole, as *N* is to the inhabitant *n* on the North Pole: ſo is *E* to the inhabitant *e* ſuppoſed to be on the North end of *Peru*; and *Q* to the oppoſite inhabitant *q* on the middle of the iſland *Sumatra*. Each of theſe obſervers is ſurpriſed that his oppoſite or *Antipode* can ſtand with his head hanging downward. But let either

PLATE II. Fig. I.

Antipodes.

11

Pl. II.

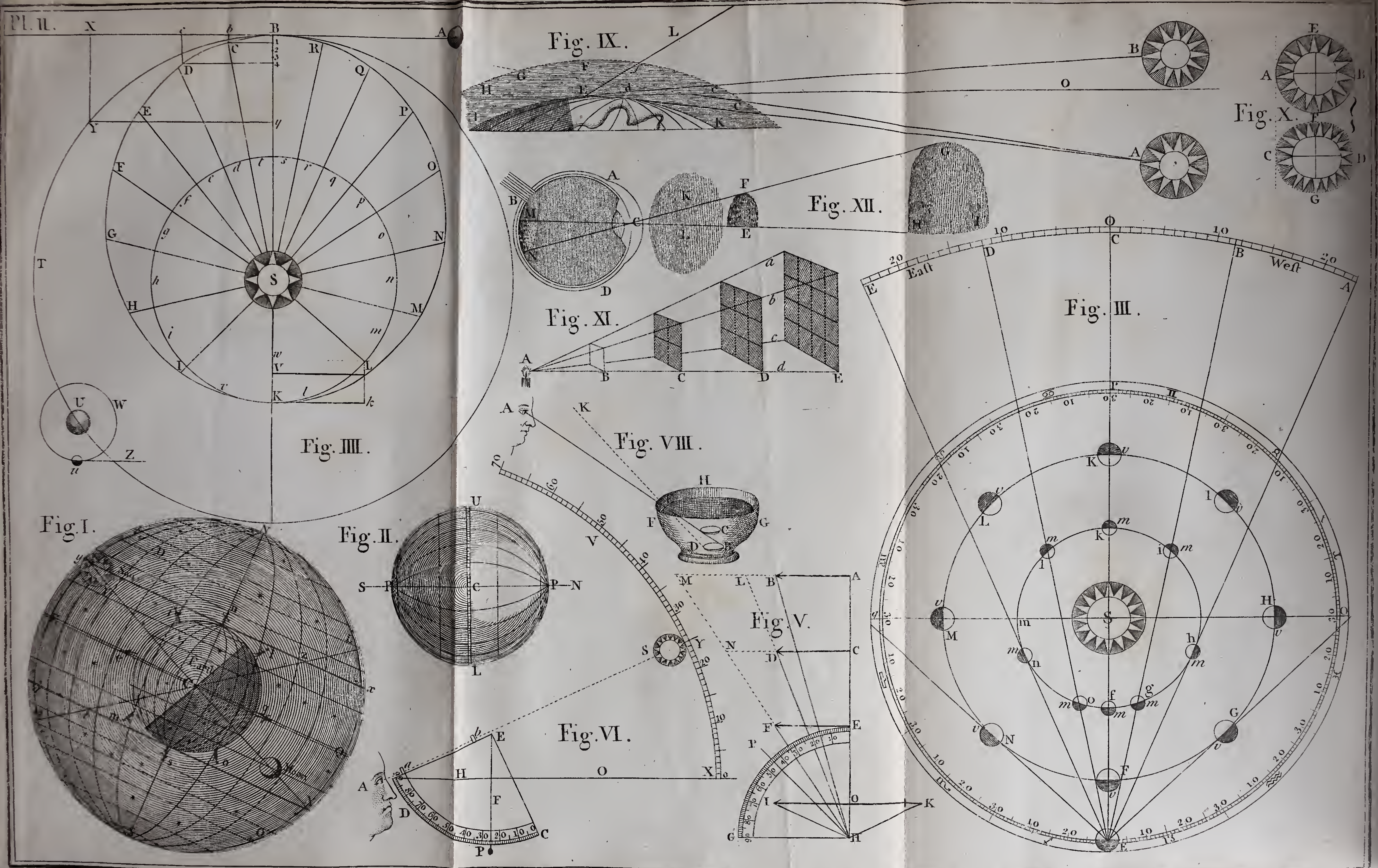


Fig. I.
Fig. II.
Fig. III.
Fig. IIII.
Fig. V.
Fig. VI.
Fig. VIII.
Fig. IX.
Fig. X.
Fig. XI.
Fig. XII.
East
West
Moon

either go to the other, and he will tell him that he ſtood as upright and firm on the place where he was, as he now ſtands where he is. To all theſe obſervers the Sun, Moon, and Stars, ſeem to turn round the points *N* and *S*, as the Poles of the fixed Axis *NCS*; becauſe the Earth does really turn round the mathematical line *nCs* as round an Axis, of which *n* is the North Pole, and *s* the South Pole. The inhabitant *U* (Fig. II.) affirms, that he is on the uppermoſt ſide of the Earth, and wonders how another at *L* can ſtand on the undermoſt ſide with his head hanging downwards. But *U* in the mean time forgets that in twelve hours time he will be carried half round with the Earth, and then be in the very ſituation that *L* now is, although as far from him as before. And yet, when *U* comes there, he will find no difference as to his manner of ſtanding; only he will ſee the oppoſite half of the Heavens, and imagine the Heavens to have gone half round the Earth.

PLATE II. Axis of the World. Its Poles. Fig. II.

123. When we ſee a Globe hung up in a room, we cannot help imagining it to have an upper and an under ſide, and immediately form a like idea of the Earth; from whence we conclude, that it is as impoſſible for people to ſtand on the under ſide of the Earth, as for pebbles to lie on the under ſide of a common Globe, which inſtantly fall down from it to the ground; and well they may, becauſe the attraction of the Earth being greater than the attraction of the Globe, pulls them away. Juſt ſo would be the caſe with our Earth, if it were placed near a Globe much bigger than itſelf, ſuch as Jupiter: for then it would really have an upper and an under ſide with reſpect to that large Globe; which, by its Attraction, would pull away every thing from the ſide of the Earth next to it; and only thoſe on its ſurface at the oppoſite ſide could remain upon it. But there is no larger Globe near enough our Earth to overcome its central attraction;

How our Earth might have an upper and an under ſide.

PLATE II. attraction; and therefore it has no ſuch thing as an upper and an under ſide; for all bodies on or near its ſurface, even to the Moon, gravitate toward its center.

124. Let any man imagine that the Earth and every thing but himſelf is taken away, and he left alone in the midſt of indefinite ſpace; he could then have no idea of *up* or *down*; and were his pockets full of gold, he might take the pieces one by one, and throw them away on all ſides of him, without any danger of loſing them; for the attraction of his body would bring them all back by the way they went, and *he* would be *down* to every one of them. But then, if a Sun or any other large body were created, and placed in any part of Space ſeveral millions of miles from him, he would be attracted toward it, and could not ſave himſelf from falling *down* to it.

Fig. I.

Half of the Heavens viſible to an inhabitant on any part of the Earth.

125. The Earth's bulk is but a point, as that at *C*, compared to the Heavens; and therefore every inhabitant upon it, let him be where he will, as at *n*, *e*, *m*, *s*, &c. ſees half of the Heavens. The inhabitant *n*, on the North Pole of the Earth, conſtantly ſees the Hemiſphere *ENQ*; and having the North Pole *N* of the Heavens juſt over his head, his Horizon * coincides with the Celeſtial Equator *ECQ*. Therefore all the Stars in the Northern Hemiſphere *ENQ*, between the Equator and North Pole, appear to turn round the line *NC*, moving parallel to the Horizon. The Equatorial Stars keep in the Horizon, and all thoſe in the Southern Hemiſphere *ESQ* are inviſible. The like Phenomena are ſeen by the obſerver *s* on the South Pole, with reſpect to the Hemiſphere *ESQ*, and to him the oppoſite Hemiſphere is always inviſible. Hence, under either Pole, only one

* The utmoſt limit of a perſon's view, where the Sky ſeems to touch the Earth all around, is called his Horizon; which ſhifts as the perſon changes his place.

half

half of the Heavens is ſeen; for thoſe parts which are once viſible never ſet, and thoſe which are once inviſible never riſe. But the Ecliptic *ϒCX*, or Orbit which the Sun appears to deſcribe once a-year by the Earth's annual motion, has the half *ϒC* conſtantly above the Horizon *ECQ* of the North Pole *n*; and the other half *CX* always below it. Therefore while the Sun deſcribes the northern half *ϒC* of the Ecliptic, he neither ſets to the North Pole nor riſes to the South; and while he deſcribes the ſouthern half *CX*, he neither ſets to the South Pole, nor riſes to the North. The ſame things are true with reſpect to the Moon; only with this difference, that as the Sun deſcribes the Ecliptic but once a-year, he is for half that time viſible to each Pole in its turn, and as long inviſible; but as the Moon goes round the Ecliptic in 27 days 8 hours, ſhe is only viſible for 13 days 16 hours, and as long inviſible to each Pole by turns. All the Planets likewiſe riſe and ſet to the Poles, becauſe their Orbits are cut obliquely in halves by the Horizon of the Poles. When the Sun (in his apparent way from *X*) arrives at *C*, which is on the 20th of *March*, he is juſt riſing to an obſerver at *n* on the North Pole, and ſetting to another at *s* on the South Pole. From *C* he riſes higher and higher in every apparent Diurnal revolution, till he comes to the higheſt point of the Ecliptic *y*, on the 21ſt of *June*, and then he is at his greateſt altitude, which is 23½ degrees, or the Arc *Ey*, equal to his greateſt north declination; and from thence he ſeems to deſcend gradually in every apparent Circumvolution, till he ſets at *C* on the 23d of *September*; and then he goes to exhibit the like Appearances at the South Pole for the other half of the year. Hence the Sun's apparent motion round the Earth is not in parallel Circles, but in Spirals; ſuch as might be repreſented by a thread wound round a Globe from Tropic to Tropic; the Spirals being at ſome diſtance from one another about the Equator, and gradually

Phenomena at the Poles

PLATE II. gradually nearer to each other as they approach toward the Tropics.

Phenomena at the Equator. 126. If the obſerver be any where on the Terreſtrial Equator *e C q*, as ſuppoſe at *e*, he is in the plane of the Celeſtial Equator; or under the Equinoctial *E C Q*; and the Axis of the Earth *n C s* is coincident with the plane of his Horizon, extended out to *N* and *S*, the North and South Poles of the Heavens. As the Earth turns round the line *N C S*, the whole Heavens *M O L l* ſeem to turn round the ſame line, but the contrary way. It is plain that this obſerver has the Celeſtial Poles conſtantly in his Horizon, and that his Horizon cuts the Diurnal paths of all the Celeſtial bodies perpendicularly, and in halves. Therefore the Sun, Planets, and Stars, riſe every day, and aſcend perpendicularly above the Horizon for ſix hours, and paſſing over the Meridian, deſcend in the ſame manner for the ſix following hours; then ſet in the Horizon, and continue twelve hours below it. Conſequently at the Equator the days and nights are equally long throughout the year. When the obſerver is in the ſituation *e*, he ſees the Hemiſphere *S E N*; but in twelve hours after, he is carried half round the Earth's Axis to *q*, and then the Hemiſphere *S Q N* becomes viſible to him; and *S E N* diſappears. Thus we find, that to an obſerver at either of the Poles one half of the Sky is always viſible, and the other half never ſeen; but to an obſerver on the Equator the whole Sky is ſeen every 24 hours. (Fig. I.)

The Figure here referred to, repreſents a Celeſtial globe of glaſs, having a Terreſtrial Globe within it: after the manner of the Glaſs Sphere invented by my generous friend Dr. Long, *Lowndes's* Profeſſor of Aſtronomy in *Cambridge*.

Remark. 127. If a Globe be held ſidewiſe to the eye, at ſome diſtance, and ſo that neither of its Poles can be ſeen, the Equator *E C Q*, and all Circles parallel to it, as *D L*, *y z x*, *a b X*, *M O*, &c. will appear to be ſtraight

ſtraight lines, as projected in this Figure; which is requiſite to be mentioned here, becauſe we ſhall have occaſion to call them Circles in the following Articles of this Chapter*.

Phenomena between the Equator and Poles.

128. Let us now ſuppoſe that the obſerver has gone from the Equator *e* toward the North Pole *n*, and that he ſtops at *i*, from which place he then ſees the Hemiſphere *MEINL*; his Horizon *MCL* having ſhifted as many Degrees † from the Celeſtial Poles *N* and *S*, as he has travelled from under the Equinoctial *E*. And as the Heavens ſeem conſtantly to turn round the line *NCS* as an Axis, all thoſe Stars which are not ſo many degrees from the North Pole *N* as the obſerver is from the Equinoctial, namely, the Stars north of the dotted parallel *DL*, never ſet below the Horizon; and thoſe which are ſouth of the dotted parallel *MO* never riſe above it. Hence the former of theſe two parallel Circles is called *the Circle of perpetual Apparition*, and the latter *the Circle of perpetual Occultation:* but all the Stars between theſe two Circles riſe and ſet every day. Let us imagine many Circles to be drawn between theſe two, and parallel to them; thoſe which are on the north ſide of the Equinoctial will be unequally cut by the Horizon *MCL*, having larger portions above the Horizon than below it; and the more ſo, as they are nearer to the Circle of perpetual Apparition; but the reverſe happens to thoſe on the ſouth ſide of the Equinoctial, while the Equinoctial is divided in two equal parts by the Horizon. Hence, by the apparent turning of the Heavens, the northern Stars deſcribe greater Arcs or Portions of Circles above the Horizon than below it; and the greater, as they are farther from the Equinoctial toward the Circle of perpetual Apparition; while the contrary

The Circles of perpetual Apparition and Occultatiou.

* The Plane of a Circle, or a thin circular Plate, being turned edgewiſe to the eye, appears to be a ſtraight line.

† A Degree is the 360th part of a Circle.

trary happens to all Stars ſouth of the Equinoctial: but thoſe upon it deſcribe equal Arcs both above and below the Horizon, and therefore they are juſt as long above as below it.

129. An obſerver on the Equator has no Circle of perpetual Apparition or Occultation, becauſe all the Stars, together with the Sun and Moon, riſe and ſet to him every day. But, as a bare view of the Figure is ſufficient to ſhew that theſe two Circles *DL* and *MO* are juſt as far from the Poles *N* and *S* as the obſerver at *i* (or one oppoſite to him at *o*) is from the Equator *ECQ*; it is plain, that if an obſerver begins to travel from the Equator toward either Pole, his Circle of perpetual Apparition riſes from that Pole as from a Point, and his Circle of perpetual Occultation from the other. As the obſerver advances toward the nearer Pole, theſe two Circles enlarge their diameters, and come nearer one another, until he comes to the Pole; and then they meet and coincide in the Equinoctial. On different ſides of the Equator, to obſervers at equal diſtances from it, the Circle of perpetual Apparition to one is the Circle of perpetual Occultation to the other.

Why the Stars always deſcribe the ſame parallel of motion, and the Sun a different.

130. Becauſe the Stars never vary their diſtances from the Equinoctial, ſo as to be ſenſible in an age, the lengths of their diurnal and nocturnal Arcs are always the ſame to the ſame places on the Earth. But as the Earth goes round the Sun every year in the Ecliptic, one half of which is on the north ſide of the Equinoctial, and the other half on its ſouth ſide, the Sun appears to change his place every day, ſo as to go once round the Circle *YCX* every year, § 114. Therefore while the Sun appears to advance northward, from having deſcribed the parallel *abX* touching the Ecliptic in *X*, the days continually lengthen and the nights ſhorten, until he comes to *y* and deſcribes the parallel *yzx*, when the days are at the longeſt and the nights at the

the ſhorteſt: for then, as the Sun goes no farther northward, the greateſt portion that is poſſible of the diurnal Arc *yz* is above the Horizon of the inhabitant *i*; and the ſmalleſt portion *zx* below it. As the Sun declines ſouthward from *y*, he deſcribes ſmaller diurnal and greater nocturnal Arcs, or Portions of Circles, every day; which cauſes the days to ſhorten and nights to lengthen, until he arrives again at the Parallel *abX*; which having only the ſmall part *ab* above the Horizon *MCL*, and the great part *bX* below it, the days are at the ſhorteſt and the nights at the longeſt: becauſe the Sun recedes no farther ſouth, but returns northward as before. It is eaſy to ſee that the Sun muſt be in the Equinoctial *ECQ* twice every year, and then the days and nights are equally long; that is, 12 hours each. Theſe hints ſerve at preſent to give an idea of ſome of the Appearances reſulting from the motions of the Earth; which will be more particularly deſcribed in the tenth Chapter. PLATE II.

131. To an obſerver at either Pole, the Horizon and Equinoctial are coincident; and the Sun and Stars ſeem to move parallel to the Horizon: therefore ſuch an obſerver is ſaid to have a parallel poſition of the Sphere. To an obſerver any where between either Pole and Equator, the Parallels deſcribed by the Sun and Stars are cut obliquely by the Horizon, and therefore he is ſaid to have an oblique poſition of the Sphere. To an obſerver any where on the Equator, the Parallels of Motion, deſcribed by the Sun and Stars, are cut perpendicularly, or at Right Angles, by the Horizon; and therefore he is ſaid to have a right poſition of the Sphere. And theſe three are all the different ways that the Sphere can be poſited to all people on the Earth. Fig. I. Parallel, Oblique, and Right Sphere, what.

CHAP.

CHAP. V.

The Phenomena of the Heavens as ſeen from different Parts of the Solar Syſtem.

132. SO vaſtly great is the diſtance of the ſtarry Heavens, that if viewed from any part of the Solar Syſtem, or even many millions of miles beyond it, the appearance would be the very ſame to us. The Sun and Stars would all ſeem to be fixed on one concave ſurface, of which the ſpectator's eye would be the center. But the Planets, being much nearer than the Stars, their appearances will vary conſiderably with the Place from which they are viewed.

133. If the ſpectator is at reſt without their Orbits, the Planets will ſeem to be at the ſame diſtance as the Stars; but continually changing their places with reſpect to the Stars, and to one another: aſſuming various phaſes of increaſe and decreaſe like the Moon; and, notwithſtanding their regular motions about the Sun, will ſometimes appear to move quicker, ſometimes ſlower, be as often to the weſt as to the eaſt of the Sun; and at their greateſt diſtances ſeem quite ſtationary. The duration, extent, and diſtance, of thoſe points in the Heavens where theſe digreſſions begin and end, would be more or leſs, according to the reſpective diſtances of the ſeveral Planets from the Sun: but in the ſame Planet they would continue invariably the ſame at all times; like pendulums of unequal lengths oſcillating together, the ſhorter move quick and go over a ſmall ſpace, the longer move ſlow and go over a large ſpace. If the obſerver is at reſt within the Orbits of the Planets but not near the common center, their apparent motions will be irregular, but leſs ſo than in the former caſe. Each of the ſeveral Planets will appear bigger and leſs by turns, as they approach nearer

nearer to or recede farther from the obſerver: the neareſt varying moſt in their ſize. They will alſo move quicker or ſlower with regard to the fixed Stars, but will never be retrograde or ſtationary.

134. If an obſerver in motion views the Heavens, the ſame apparent irregularities will be obſerved, but with ſome variation reſulting from his own motion. If he is on a Planet which has a rotation on its Axis, not being ſenſible of his own motion, he will imagine the whole Heavens, Sun, Planets, and Stars, to revolve about him in the ſame time that his Planet turns round, but the contrary way; and will not be eaſily convinced of the deception. If his Planet moves round the Sun, the ſame irregularities and aſpects as above-mentioned will appear in the motions of the other Planets; and the Sun will ſeem to move among the fixed Stars or Signs, in an oppoſite direction to that which his Planet moves in, changing its place every day as he does. In a word, whether our obſerver be in motion or at reſt, whether within or without the Orbits of the Planets, their motions will ſeem irregular, intricate, and perplexed, unleſs he is in the center of the Syſtem; and from thence, the moſt beautiful order and harmony will be ſeen by him.

The Sun's center the only point from which the true motions and places of the Planets could be ſeen.

135. The Sun being the center of all the Planets motions, the only place from which their motions could be truly ſeen, is the Sun's center; where the obſerver being ſuppoſed not to turn round with the Sun, (which, in this caſe, we muſt imagine to be a tranſparent body,) would ſee all the Stars at reſt, and ſeemingly equidiſtant from him. To ſuch an obſerver, the Planets would appear to move among the fixed Stars, in a ſimple, regular, and uniform manner: only, that as in equal times they deſcribe equal Areas, they would deſcribe ſpaces ſomewhat unequal, becauſe they move in elliptic Orbits, § 155. Their motions would alſo appear to be what they are in fact, the ſame way round the Heavens; in

paths

paths which croſs at ſmall Angles in different parts of the Heavens, and then ſeparate a little from one another, § 20. So that, if the Solar Aſtronomer ſhould make the Path or Orbit of any Planet a ſtandard, and conſider it as having no obliquity, § 201, he would judge the paths of all the reſt to be inclined to it; each Planet having one half of its path on one ſide, and the other half on the oppoſite ſide of the ſtandard Path or Orbit. And if he ſhould ever ſee all the Planets ſtart from a conjunction with each other*, Mercury would move ſo much faſter than Venus, as to overtake her again (though not in the ſame point of the Heavens) in a quantity of time almoſt equal to 145 of our days and nights, or, as we commonly call them, *Natural Days*, which include both the days and nights: Venus would move ſo much faſter than the Earth, as to overtake it again in 585 natural days: the Earth ſo much faſter than Mars, as to overtake him again in 778 ſuch days: Mars ſo much faſter than Jupiter, as to overtake him again in 817 ſuch days: and Jupiter ſo much faſter than Saturn, as to overtake him again in 7236 days, all of our time.

The judgment that a ſolar Aſtronomer would probably make concerning the diſtances and bulks of the Planets.

136. But as our ſolar Aſtronomer could have no idea of meaſuring the courſes of the Planets by our days, he would probably take the period of Mercury, which is the quickeſt moving Planet, for a meaſure to compare the periods of the others by. As all the Stars would appear quieſcent to him, he would never think that they had any dependance upon the Sun; but would naturally imagine that the Planets have, becauſe they move round the Sun. And it is by no means improbable, that he

* Here we do not mean ſuch a conjunction, as that the nearer Planet ſhould hide all the reſt from the obſerver's ſight; (for that would be impoſſible, unleſs the interſections of all their Orbits were coincident, which they are not. *See* § 21.) but when they were all in a line croſſing the ſtandard Orbit at Right Angles.

Plate III.

Fig. I.

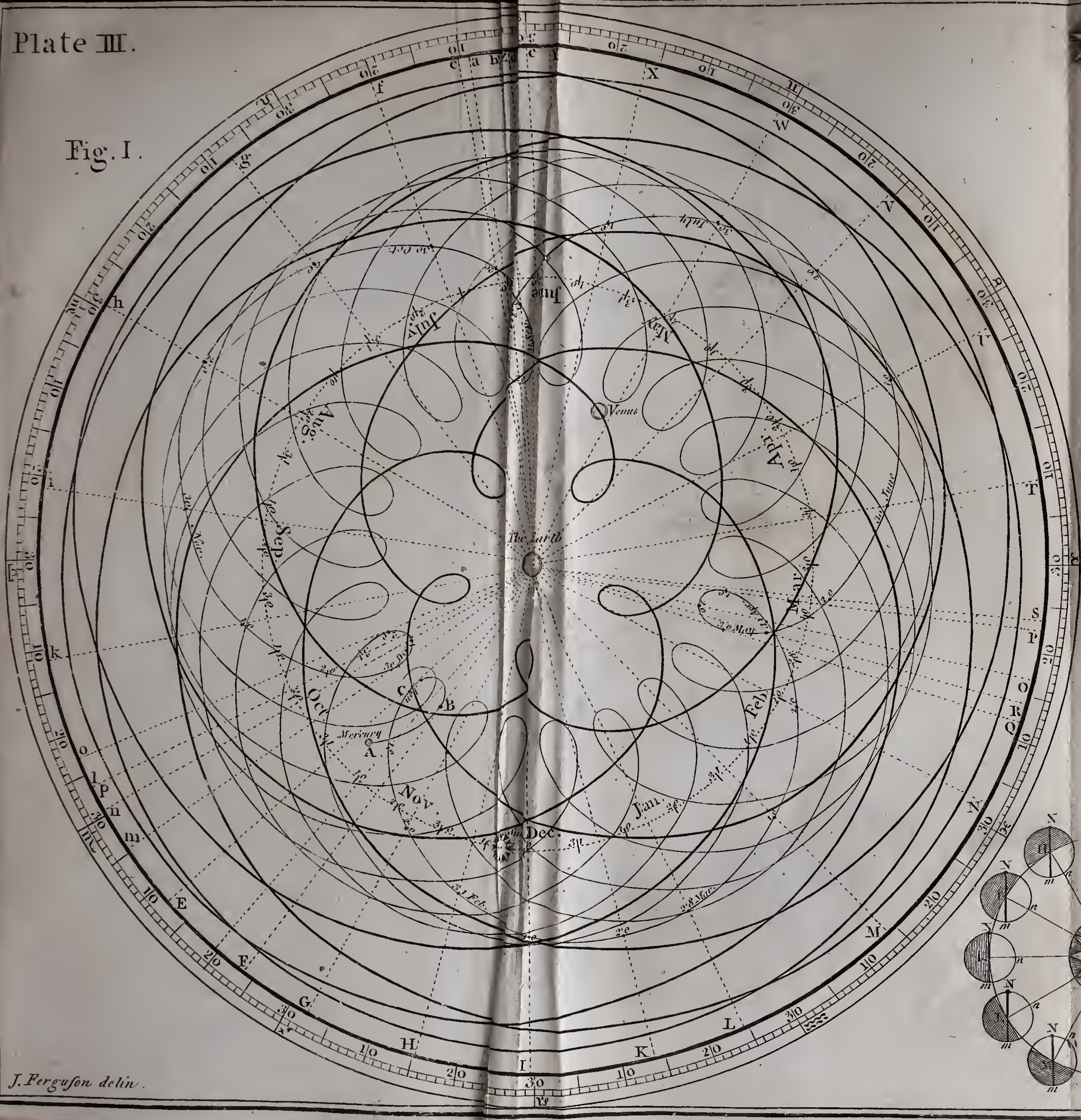


Fig. IIII.

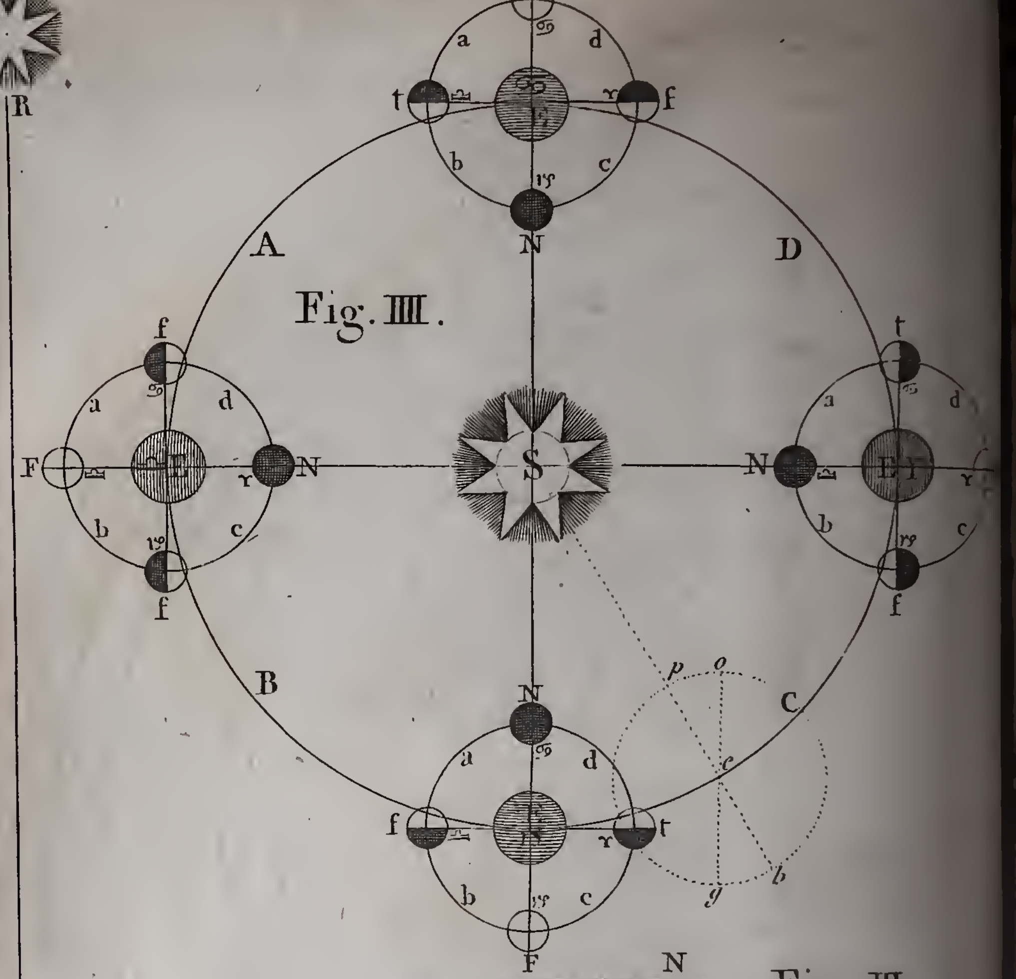


Fig. III.

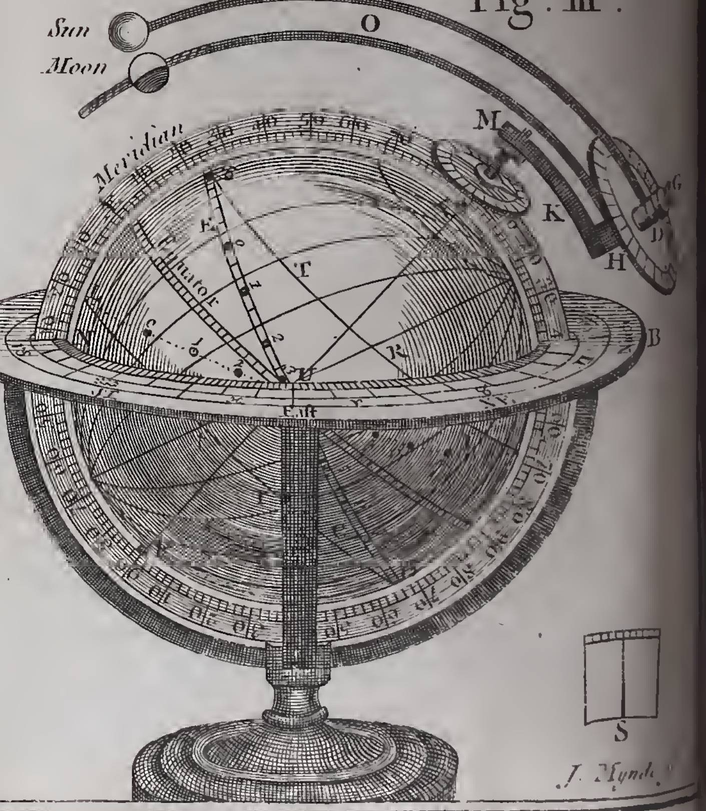
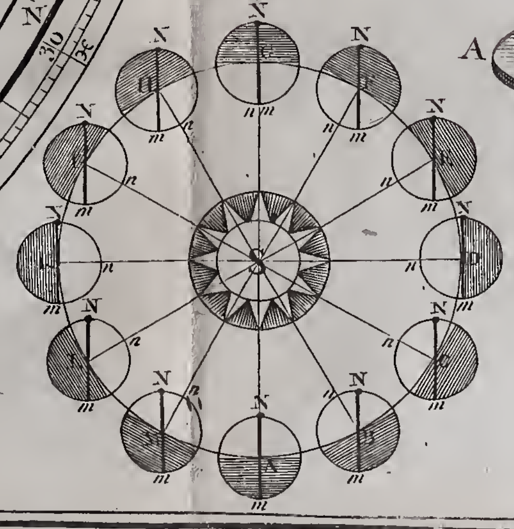


Fig. II.



J. Ferguson delin.

J. Mynde sc.

would conclude thoſe Planets, whoſe Periods are quickeſt, to move in Orbits proportionably leſs than thoſe do which make ſlower circuits. But being deſtitute of a method for finding their Parallaxes, or more properly ſpeaking, as they could have no Parallax to him, he could never know any thing of their real diſtances or magnitudes. Their relative diſtances he might perhaps gueſs at by their periods, and from thence infer ſomething of truth concerning their relative bulks, by comparing their apparent bulks with one another. For example, Jupiter appearing bigger to him than Mars, he would conclude it to be much bigger in fact; becauſe it appears ſo, and muſt be farther from him, on account of its longer period. Mercury and the Earth would ſeem much of the ſame bulk; but by comparing its period with the Earth's, he would conclude that the Earth is much farther from him than Mercury, and conſequently that it muſt be really bigger, though apparently of the ſame bulk; and ſo of the reſt. And as each Planet would appear ſomewhat bigger in one part of its Orbit than in the oppoſite, and to move quickeſt when it ſeems biggeſt, the obſerver would be at no loſs to conclude that all the Planets move in Orbits, of which the Sun is not preciſely in the center.

The Planetary motions very irregular as ſeen from the Earth.

137. The apparent magnitudes of the Planets continually change as ſeen from the Earth, which demonſtrates that they approach nearer to it, and recede farther from it by turns. From theſe Phenomena, and their apparent motions among the Stars, they ſeem to deſcribe looped curves which never return into themſelves, Venus's path excepted. And if we were to trace out all their apparent paths, and put the figures of them together in one diagram, they would appear ſo anomalous and confuſed, that no man in his ſenſes could believe them to be repreſentations of their real paths; but would immediately conclude, that ſuch appa-

PLATE III.

rent irregularities muſt be owing to ſome Optic illuſions. And after a good deal of enquiry, he might perhaps be at a loſs to find out the true cauſe of theſe irregularities; eſpecially if he were one of thoſe who would rather, with the greateſt juſtice, charge frail man with ignorance, than the Almighty with being the author of ſuch confuſion.

Thoſe of Mercury and Venus repreſented.

138. Dr. LONG, in his firſt volume of *Aſtronomy*, has given us figures of the apparent paths of all the Planets, ſeparately from CASSINI; and on ſeeing them I firſt thought of attempting to trace ſome of them by a machine * that ſhews the motions of the Sun, Mercury, and Venus, the Earth, and Moon, according to the *Copernican Syſtem*. Having taken off the Sun, Mercury, Venus, I put black-lead pencils in their places, with the points turned upward; and fixed a circular ſheet of paſte-board ſo, that the Earth kept conſtantly under its center in going round the Sun; and the paſte-board kept its paralleliſm. Then, preſſing gently with one hand upon the paſte-board to make it touch the three pencils, with the other hand I turned the winch that moves the whole machinery: and as the Earth, together with the pencils in the places of Mercury and Venus, had their proper motions round the Sun's pencil, which kept at reſt in the center of the machine, all the three pencils deſcribed a diagram, from which the firſt Figure of the third Plate is truly copied in a ſmaller ſize. As the Earth moved round the Sun, the Sun's pencil deſcribed the dotted Circle of Months, whilſt Mercury's pencil drew the curve with the greateſt number of loops, and Venus's that with the feweſt. In their inferior conjunctions they come as much nearer the Earth, or within the Circle of the Sun's apparent motion round the Heavens, as they go beyond it in their ſuperior conjunctions. On each ſide of the loops they appear ſtationary: in that part of

Fig. I.

* The ORRERY fronting the Title-Page.

 each

each loop next the Earth retrograde; and in all the reſt of their paths direct. PLATE III.

If *Caſſini*'s Figures of the paths of the Sun, Mercury, and Venus, were put together, the Figure as above traced out would be exactly like them. It repreſents the Sun's apparent motion round the Ecliptic, which is the ſame every year; Mercury's motion for ſeven years; and Venus's for eight; in which time Mercury's path makes 23 loops, croſſing itſelf ſo many times, and Venus's only five. In eight years Venus falls ſo nearly into the ſame apparent path again, as to deviate very little from it in ſome ages; but in what number of years Mercury and the reſt of the Planets would deſcribe the ſame viſible paths over again, I cannot at preſent determine. Having finiſhed the above Figure of the paths of Mercury and Venus, I put the Ecliptic round them as in the Doctor's Book; and added the dotted lines from the Earth to the Ecliptic for ſhewing Mercury's apparent or geocentric motion therein for one year; in which time his path makes three loops, and goes on a little farther; which ſhews that he has three inferior, and as many ſuperior conjunctions with the Sun in that time; and alſo that he is ſix times ſtationary, and thrice retrograde. Let us now trace his motion for one year in the Figure.

Suppoſe Mercury to be ſetting out from *A* toward *B* (between the Earth and left-hand corner of the Plate) and as ſeen from the Earth, his motion will then be direct, or according to the order of the Signs. But when he comes to *B*, he appears to ſtand ſtill in the 23d degree of ♏ at *F*, as ſhewn by the line *B F*. While he goes from *B* to *C*, the line *B F*, ſuppoſed to move with him, goes backward from *F* to *E*, or contrary to the order of Signs; and when he is at *C*, he appears ſtationary at *E*; having gone back $11\frac{1}{2}$ degrees. Now, ſuppoſe him ſtationary on the firſt of *January* at *C*, on the 10th of that month he will appear in the Heavens Fig. I.

as at 20, near *F*; on the 20th he will be ſeen as at *G*; on the 31ſt at *H*; on the 10th of *February* at *I*; on the 20th at *K*; and on the 28th at *L*; as the dotted lines ſhew, which are drawn through every tenth day's motion in his looped path, and continued to the Ecliptic. On the 10th of *March* he appears at *M*; on the 20th at *N*; and on the 31ſt at *O*. On the 10th of *April* he appears ſtationary at *P*; on the 20th he ſeems to have gone back again to *O*; and on the 30th he appears ſtationary at *Q*, having gone back 11½ degrees. Thus Mercury ſeems to go forward 4 Signs 11 Degrees, or 131 Degrees; and to go back only 11 or 12 Degrees, at a mean rate. From the 30th of *April* to the 10th of *May*, he ſeems to move from *Q* to *R*; and on the 20th he is ſeen at *S*, going forward in the ſame manner again, according to the order of letters; and backward when they go back; which it is needleſs to explain any farther, as the reader can trace him out ſo eaſily, through the reſt of the year. The ſame appearances happen in Venus's motion; but as ſhe moves ſlower than Mercury, there are longer intervals of time between them.

Having already, § 120, given ſome account of the apparent diurnal motions of the Heavens as ſeen from the different Planets, we ſhall not trouble the reader any more with that ſubject.

CHAP. VI.

The Ptolemean *Syſtem refuted. The Motions and Phaſes of Mercury and Venus explained.*

139. THE *Tychonic Syſtem*, § 97, being ſufficiently refuted by the 109th Article, we ſhall ſay nothing more about it.

140. The *Ptolemean Syſtem*, § 96, which aſſerts the Earth to be at reſt in the Center of the Universe, and all the Planets with the Sun and Stars to move round it, is evidently falſe and abſurd. For

For if this hypothesis were true, Mercury and Venus could never be hid behind the Sun, as their Orbits are included within the Sun's: and again, these two Planets would always move direct, and be as often in Opposition to the Sun as in Conjunction with him. But the contrary of all this is true: for they are just as often behind the Sun as before him, appear as often to move backward as forward, and are so far from being seen at any time in the side of the Heavens opposite to the Sun, that they were never seen a quarter of a circle in the Heavens distant from him.

141. These two Planets, when viewed at different times with a good telescope, appear in all the various shapes of the Moon; which is a plain proof that they are enlightened by the Sun, and shine not by any light of their own: for if they did, they would constantly appear round as the Sun does; and could never be seen like dark spots upon the Sun when they pass directly between him and us. Their regular Phases demonstrate them to be spherical bodies; as may be shewn by the following experiment: **Appearances of Mercury and Venus.**

Hang an ivory ball by a thread, and let any person move it round the flame of a candle, at two or three yards distance from your eye; when the ball is beyond the candle, so as to be almost hid by the flame, its enlightened side will be toward you, and appear round like the Full Moon: when the ball is between you and the candle, its enlightened side will disappear, as the Moon does at the Change: when it is half way between these two positions, it will appear half illuminated, like the Moon in her Quarters: but in every other place between these positions, it will appear more or less horned or gibbous. If this experiment be made with a flat circular plate, you may make it appear fully enlightened, or not enlightened at all; but can never make it seem either horned or gibbous. **Experiment to prove they are round.**

PLATE II.

Experiment to reprefent the motions of Mercury and Venus.

142. If you remove about fix or feven yards from the candle, and place yourfelf fo that its flame may be juft about the height of your eye, and then defire the other perfon to move the ball flowly round the candle as before, keeping it as near of an equal height with the flame as he poffibly can, the ball will appear to you not to move in a circle, but to vibrate backward and forward like a pendulum, moving quickeft when it is directly between you and the candle, and when directly beyond it; and gradually flower as it goes farther to the right or left fide of the flame, until it appears at the greateft diftance from the flame; and then, though it continues to move with the fame velocity, it will feem to ftand ftill for a moment. In every Revolution it will fhew all the above Phafes, § 141; and if two balls, a fmaller and a greater, be moved in this manner round the candle, the fmaller ball being kept neareft the flame, and carried round almoft three times as often as the greater, you will have a tolerable good reprefentation of the apparent Motions of Mercury and Venus; efpecially if the bigger ball defcribes a circle almoft twice as large in diameter as the circle defcribed by the leffer.

Fig. III.

143. Let *ABCDE* be a part or fegment of the vifible Heavens, in which the Sun, Moon, Planets, and Stars, appear to move at the fame diftance from the Earth *E*. For there are certain limits, beyond which the eye cannot judge of different diftances; as is plain from the Moon's appearing to be as far from us as the Sun and Stars are. Let the circle *fghiklmno* be the Orbit in which Mercury *m* moves round the Sun *S*, according to the order of the letters. When Mercury is at *f*, he difappears to the Earth at *E*, becaufe his enlightened fide is turned from it; unlefs he be then in one of his Nodes, § 20. 25; in which cafe he will appear like a dark fpot upon the Sun. When he is at *g* in his Orbit, he appears at *B* in the Heavens weft-ward

The Elongations or Digreffions of Mercury from the Sun.

ward of the Sun *S*, which is ſeen at *C*: when at *h*, he appears at *A*, at his greateſt weſtern elongation or diſtance from the Sun; and then ſeems to ſtand ſtill. But, as he moves from *h* to *i*, he appears to go from *A* to *B*; and ſeems to be in the ſame place when at *i*, as when he was at *g*, but not near ſo big: at *k* he is hid from the Earth *E* by the Sun *S*; being then in his ſuperior Conjunction. In going from *k* to *l*, he appears to move from *C* to *D*; and when he is at *n*, he appears ſtationary at *E*; being ſeen as far eaſt from the Sun then, as he was weſt from it at *A*. In going from *n* to *o* in his Orbit, he ſeems to go back again in the Heavens, from *E* to *D*; and is ſeen in the ſame place (with reſpect to the Sun) at *o*, as when he was at *l*; but of a larger diameter at *o*, becauſe he is then nearer the Earth *E*: and when he comes to *f*, he again paſſes by the Sun, and diſappears as before. In going from *n* to *h* in his Orbit, he ſeems to go backward in the Heavens from *E* to *A*; and in going from *h* to *n*, he ſeems to go forward from *A* to *E*, as he goes on from *f*, a little of his enlightened ſide at *g* is ſeen from *E*; at *h* he appears half full, becauſe half of his enlightened ſide is ſeen; at *i*, gibbous, or more than half full; and at *k* he would appear quite full, were he not hid from the Earth *E* by the Sun *S*. At *l* he appears gibbous again: at *n* half decreaſed, at *o* horned, and at *f* new like the Moon at her Change. He goes ſooner from his eaſtern ſtation at *n* to his weſtern ſtation at *h*, than from *h* to *n* again; becauſe he goes through leſs than half his Orbit in the former caſe, and more in the latter. PLATE II.

144. In the ſame Figure, let *FGHIKLMN* be the Orbit in which Venus *v* goes round the Sun *S*, according to the order of the letters: and let *E* be the Earth as before. When Venus is at *F*, ſhe is in her inferior Conjunction; and diſappears like the New Moon, becauſe her dark ſide is toward the Earth. At *G*, ſhe appears half enlightened to Fig. III. The Elongations and phaſes of Venus.

to the Earth, like the Moon in her firſt quarter: at *H*, ſhe appears gibbous; at *I*, almoſt full; her enlightened ſide being then nearly towards the Earth: at *K* ſhe would appear quite full to the Earth *E*; but is hid from it by the Sun *S*: at *L*, ſhe appears upon the decreaſe, or gibbous; at *M*, more ſo; at *N*, only half enlightened; and at *F*, ſhe diſappears again. In moving from *N* to *G*, ſhe ſeems to go backward in the Heavens; and from *G* to *N*, forward; but as ſhe deſcribes a much greater portion of her Orbit in going from *G* to *N*, than from *N* to *G*, ſhe appears much longer direct than retrograde in her motion. At *N* and *G* ſhe appears ſtationary; as Mercury does at *n* and *b*. Mercury, when ſtationary, ſeems to be only 28 degrees from the Sun; and Venus when ſo, 47; which is a demonſtration that Mercury's Orbit is included within Venus's, and Venus's within the Earth's.

The greateſt Elongations of Mercury and Venus.

145. Venus, from her ſuperior Conjunction at *K* to her inferior Conjunction at *F*, is ſeen on the eaſt ſide of the Sun *S* from the Earth *E*; and therefore ſhe ſhines in the Evening after the Sun ſets, and is called *the Evening Star*: for, the Sun being then to the weſtward of Venus, he muſt ſet firſt. From her inferior Conjunction to her ſuperior, ſhe appears on the weſt ſide of the Sun; and therefore riſes before him, for which reaſon ſhe is called *the Morning Star*. When ſhe is about *N* or *G*, ſhe ſhines ſo bright, that bodies caſt ſhadows in the night-time.

Morning and Evening Star, what.

146. If the Earth kept always at *E*, it is evident that the ſtationary places of Mercury and Venus would always be in the ſame points of the Heavens where they were before. For example: whilſt Mercury *m* goes from *b* to *n*, according to the order of the letters, he appears to deſcribe the arc *ABCDE* in the Heavens, direct: and while he goes from *n* to *b*, he ſeems to deſcribe the ſame arc back again, from *E* to *A*, retrograde; always at

The ſtationary places of the planets variable.

at *n* and *b* he appears ſtationary at the ſame points *E* and *A* as before. But Mercury goes round his Orbit, from *f* to *f* again, in 88 days; and yet there are 116 days from any one of his Conjunctions, or apparent Stations, to the ſame again: and the places of theſe Conjunctions and Stations are found to be about 114 degrees eaſtward from the points of the Heavens where they were laſt before; which proves that the Earth has not kept all that time at *E*, but has had a progreſſive motion in its Orbit from *E* to *t*. Venus alſo differs every time in the places of her Conjunctions and Stations; but much more than Mercury; becauſe, as Venus deſcribes a much larger Orbit than Mercury does, the Earth advances ſo much the farther in its annual path before Venus comes round again.

147. As Mercury and Venus, ſeen from the Earth, have their reſpective Elongations from the Sun, and ſtationary places; ſo has the Earth, ſeen from Mars; and Mars, ſeen from Jupiter; and Jupiter, ſeen from Saturn. That is, to every ſuperior Planet, all the inferior ones have their Stations and Elongations; as Venus and Mercury have to the Earth. As ſeen from Saturn, Mercury never goes more than $2\frac{1}{2}$ degrees from the Sun; Venus $4\frac{1}{3}$; the Earth 6; Mars $9\frac{1}{2}$; and Jupiter $33\frac{1}{4}$; ſo that Mercury, as ſeen from the Earth, has almoſt as great a Digreſſion or Elongation from the Sun, as Jupiter ſeen from Saturn. The Elongations of all Saturn's inferior planets as ſeen from him.

148. Becauſe the Earth's orbit is included within the Orbits of Mars, Jupiter, and Saturn, they are ſeen on all ſides of the Heavens; and are as often in Oppoſition to the Sun as in Conjunction with him. If the Earth ſtood ſtill, they would always appear direct in their motions; never retrograde nor ſtationary. But they ſeem to go juſt as often backward as forward; which, if gravity be allowed to exiſt, affords a ſufficient proof of the Earth's annual motion: and without its exiſtence, the Planets could never fall from the tangents of A proof of the Earth's annual Motion.

their

PLATE II. their Orbits toward the Sun, nor could a ſtone, which is once thrown up from the earth, ever fall to the earth again.

149. As Venus and the Earth are ſuperior Planets to Mercury, they ſhew much the ſame Appearances to him that Mars and Jupiter do to us. Let Mercury *m* be at *f*, Venus *v* at *F*, and the Earth at *E*; in which ſituation Venus hides the Earth from Mercury; but, being in oppoſition to the Sun, ſhe ſhines on Mercury with a full illumined Orb; though, with reſpect to the Earth, ſhe is in conjunction with the Sun, and inviſible. When Mercury is at *f*, and Venus at *G*, her enlightened ſide not being directly toward him, ſhe appears a little gibbous; as Mars does in a like ſituation to us: but, when Venus is at *I*, her enlightened ſide is ſo much toward Mercury at *f*, that ſhe appears to him almoſt of a round figure. At *K*, Venus diſappears to Mercury at *f*, being then hid by the Sun; as well as all our ſuperior Planets are to us, when in conjunction with the Sun. When Venus has, as it were, emerged out of the Sun-beams, as at *L*, ſhe appears almoſt full to Mercury at *f*; at *M* and *N*, a little gibbous; quite full at *F*, and largeſt of all; being then in oppoſition to the Sun, and conſequently neareſt to Mercury at *F*; ſhining ſtrongly on him in the night, becauſe her diſtance from him then is ſomewhat leſs than a fifth part of her diſtance from the Earth, when ſhe appears roundeſt to it between *I* and *K*, or between *K* and *L*, as ſeen from the Earth *E*. Conſequently, when Venus is oppoſite to the Sun as ſeen from Mercury, ſhe appears more than 25 times as large to him as ſhe does to us when at the fulleſt. Our caſe is almoſt ſimilar with reſpect to Mars, when he is oppoſite to the Sun; becauſe he is then ſo near the Earth, and has his whole enlightened ſide toward it. But, becauſe the Orbits of Jupiter and Saturn are very large in proportion to the Earth's Orbit, theſe two Planets appear much leſs magnified

Fig. III. General Phenomena of a ſuperior Planet to an inferior.

fied at their Oppositions, or diminished at their Conjunctions, than Mars does, in proportion to their mean apparent Diameters. PLATE II.

CHAP. VII.

The physical Causes of the Motions of the Planets. The Excentricities of their Orbits. The Times in which the Action of Gravity would bring them to the Sun. ARCHIMEDES's *ideal Problem for moving the Earth. The World not eternal.*

150. FROM the uniform projectile motion of bodies in straight lines and the universal power of attraction which draws them off from these lines, the curvilineal motions of all the Planets arise If the body *A* be projected along the right line *ABX*, in open Space, where it meets with no resistance, and is not drawn aside by any other power, it will for ever go on with the same velocity, and in the same direction. For, the force which moves it from *A* to *B* in any given time, will carry it from *B* to *X* in as much more time, and so on, there being nothing to obstruct or alter its motion. But if, when this projectile force has carried it, suppose to *B*, the body *S* begins to attract it, with a power duly adjusted, and perpendicular to its motion at *B*, it will then be drawn from the straight line *ABX*, and forced to revolve about *S* in the circle *BYTU*. When the body *A* comes to *U*, or any other part of its Orbit, if the small body *u*, within the sphere of *U*'s attraction, be projected as in the right line *Z*, with a force perpendicular to the attraction of *U*, then *u* will go round *U* in the Orbit *W*, and accompany it in its whole course round the body *S*. Here *S* may represent the Sun, *U* the Earth, and *u* the Moon.

Gravitation and Projection. Fig. IV.

Circular Orbits.

Fig. IV.

151. If a planet at *B* gravitates, or is attracted, toward the Sun, so as to fall from *B* to *y* in the time

time that the projectile force would have carried it from *B* to *X*, it will describe the curve *BY* by the combined action of these two forces, in the same time that the projectile force singly would have carried it from *B* to *X*, or the gravitating power singly have caused it to descend from *B* to *y*; and these two forces being duly proportioned, and perpendicular to each other, the Planet obeying them both will move in the circle *BYTU**.

152. But if, while the projectile force would carry the Planet from *B* to *b*, the Sun's attraction (which constitutes the Planet's gravitation) should bring it down from *B* to 1, the gravitating power would then be too strong for the projectile force; and would cause the Planet to describe the curve *BC*. Elliptical Orbits. When the Planet comes to *C*, the gravitating power (which always increases as the square of the distance from the Sun *S* diminishes) will be yet stronger for the projectile force; and by conspiring in some degree therewith, will accelerate the Planet's motion all the way from *C* to *K*; causing it to describe the arcs *BC*, *CD*, *DE*, *EF*, &c. all in equal times. Having its motion thus accelerated, it thereby gains so much centrifugal force, or tendency to fly off at *K* in the line *Kk*, as overcomes the Sun's attraction: and the centrifugal force being too great to allow the Planet to be brought nearer the Sun, or even to move round him in the circle *Klmn*, &c. it goes off, and ascends in the curve *KLMN*, &c. its motion decreasing as gradually from *K* to *B*, as it increased from *B* to *K*, because the Sun's attraction now acts against the Planet's projectile motion just as much as it acted with it before. When the Planet has got round to *B*, its projectile force is as much diminished from its mean state about *G*

* To make the projectile force balance the gravitating power so exactly as that the body may move in a Circle, the projectile velocity of the body must be such as it would have acquired by gravity alone in falling through half the radius of the circle.

or

or *N*, as it was augmented at *K*; and so, the Sun's attraction being more than sufficient to keep the Planet from going off at *B*, it describes the same Orbit over again, by virtue of the same forces or powers.

PLATE II.

153. A double projectile force will always balance a quadruple power of gravity. Let the Planet at *B* have twice as great an impulse from thence toward *X*, as it had before; that is, in the same length of time that it was projected from *B* to *b*, as in the last example, let it now be projected from *B* to *c*; and it will require four times as much gravity to retain it in its Orbit; that is, it must fall as far as from *B* to 4 in the time that the projectile force would carry it from *B* to *c*; otherwise it could not describe the curve *BD*, as is evident by the Figure. But, in as much time as the Planet moves from *B* to *C* in the higher part of its Orbit, it moves from *I* to *K*, or from *K* to *L*, in the lower part thereof; because, from the joint action of these two forces, it must always describe equal Areas in equal times, throughout its annual course. These Areas are represented by the triangles *BSC*, *CSD*, *DSE*, *ESF*, &c. whose contents are equal to one another, quite round the Figure.

Fig. IV. The Planets describe equal Areas in equal times.

154. As the Planets approach nearer the Sun, and recede farther from him, in every Revolution; there may be some difficulty in conceiving the reason why the power of gravity, when it once gets the better of the projectile force, does not bring the Planets nearer and nearer the Sun in every Revolution, till they fall upon and unite with him; or why the projectile force, when it once gets the better of gravity, does not carry the Planets farther and farther from the Sun, till it removes them quite out of the sphere of his attraction, and causes them to go on in straight lines for ever afterward. But by considering the effects of these powers as described in the two last Articles, this difficulty will be removed.

A difficulty removed.

moved. Suppose a Planet at *B* to be carried by the projectile force as far as from *B* to *b*, in the time that gravity would have brought it down from *B* to 1: by these two forces it will describe the curve *BC*. When the Planet comes down to *K*, it will be but half as far from the Sun *S* as it was at *B*; and therefore, by gravitating four times as strongly towards him, it would fall from *K* to *V* in the same length of time that it would have fallen from *B* to 1 in the higher part of its Orbit, that is, through four times as much space; but its projectile force is then so much increased at *K*, as would carry it from *K* to *k* in the same time; being double of what it was at *B*, and is therefore too strong for the gravitating power, either to draw the Planet to the Sun, or cause it to go round him in the circle *Klmn*, &c. which would require its falling from *K* to *w*, through a greater space than gravity can draw it, while the projectile force is such as would carry it from *K* to *k*: and therefore the Planet ascends in its Orbit *KLMN*, decreasing in its velocity for the causes already assigned in § 152.

The Planetary Orbits elliptical.

155. The Orbits of all the Planets are Ellipses, very little different from Circles: but the Orbits of the Comets are very long Ellipses; and the lower focus of them all is in the Sun. If we suppose the mean distance (or middle between the greatest and least) of every Planet and Comet from the Sun to be divided into 1000 equal parts, the Excentricities of their Orbits, both in such parts and in *English* miles, will be as follow: Mercury's, 210 parts, or 6,720,000 miles; Venus's, 7 parts, or 413,000 miles; the Earth's, 17 parts, or 1,377,000 miles; Mars's, 93 parts, or 11,439,000 miles; Jupiter's, 48 parts, or 20,353,000 miles; Saturn's, 55 parts, or 42,735,000 miles. Of the nearest of the three forementioned Comets, 1,458,000 miles; of the middlemost, 2,025,000,000 miles; and of the outermost, 6,600,000,000.

Their excentricities.

156. By

156. By the above-mentioned law, § 150 *&c seq.* bodies will move in all kinds of Ellipses, whether long or short, if the spaces they move in be void of resistance. Only those which move in the longer Ellipses have so much the less projectile force impressed upon them in the higher parts of their Orbits; and their velocities, in coming down towards the Sun, are so prodigiously increased by his attraction, that their centrifugal forces in the lower parts of their Orbits are so great, as to overcome the Sun's attraction there, and cause them to ascend again towards the higher parts of their Orbits; during which time, the Sun's attraction acting so contrary to the motions of those bodies, causes them to move slower and slower, until their projectile forces are diminished almost to nothing; and then they are brought back again by the Sun's attraction, as before.

The above laws sufficient for motions both in circular and elliptic Orbits.

157. If the projectile forces of all the Planets and Comets were destroyed at their mean distances from the Sun, their gravities would bring them down so, as that Mercury would fall to the Sun in 15 days 13 hours; Venus in 39 days 17 hours; the Earth or Moon in 64 days 10 hours; Mars in 121 days; Jupiter in 290; and Saturn in 767. The nearest Comet in 13 thousand days; the middlemost in 23 thousand days; and the outermost in 66 thousand days. The Moon would fall to the Earth in 4 days 20 hours; Jupiter's first Moon would fall to him in 7 hours, his second in 15, his third in 30, and his fourth in 71 hours. Saturn's first Moon would fall to him in 8 hours, his second in 12, his third in 19, his fourth in 68 hours, and his fifth in 336. A stone would fall to the Earth's center, if there were a hollow passage, in 21 minutes 9 seconds. Mr. WHISTON gives the following Rule for such Computations: "*It is demonstrable, that half the Period of any Planet, when it is diminished in the sesquialteral proportion of

In what times the Planets would fall to the Sun by the power of gravity.

* Astronomical Principles of Religion, p. 66.

 the

the number 1 to the number 2, or nearly in the proportion of 1000 to 2828, is the time that it would fall to the center of its Orbit. This proportion is, when a quantity or number contains another once and a half as much more.

The prodigious attraction of the Sun and Planets.

158. The quick motions of the Moons of Jupiter and Saturn round their Primaries, demonſtrate that theſe two Planets have ſtronger attractive powers than the Earth has. For the ſtronger that one body attracts another, the greater muſt be the projectile force, and conſequently the quicker muſt be the motion of that other body to keep it from falling to its primary or central Planet. Jupiter's ſecond Moon is 124 thouſand miles farther from Jupiter than our Moon is from us; and yet this ſecond Moon goes almoſt eight times round Jupiter whilſt our Moon goes only once round the Earth. What a prodigious attractive power muſt the Sun then have, to draw all the Planets and Satellites of the Syſtem towards him! and what an amazing power muſt it have required to put all theſe Planets and Moons into ſuch rapid motions at firſt! Amazing indeed to us, becauſe impoſſible to be effected by the ſtrength of all the living Creatures in an unlimited number of Worlds; but no ways hard for the Almighty, whoſe Planetarium takes in the whole Univerſe!

ARCHIMEDES's Problem for raiſing the Earth.

159. The celebrated ARCHIMEDES affirmed he could move the Earth, if he had a place at a diſtance from it to ſtand upon to manage his machinery *. This aſſertion is true in Theory, but, upon examination, will be found abſolutely impoſſible in fact, even though a proper place and materials of ſufficient ſtrength could be had.

The ſimpleſt and eaſieſt method of moving a heavy body a little way is by a lever or crow, where a ſmall weight or power applied to the long arm

* Δός πῦ ςῶ, καὶ τὸν κοσμὸν κινήσω, *i. e.* Give me a place to ſtand on, and I ſhall move the Earth.

 will

will raiſe a great weight on the ſhort one. But then the ſmall weight muſt move as much quicker than the great weight, as the latter is heavier than the former; and the length of the long arm of the lever muſt be in the ſame proportion to the length of the ſhort one. Now, ſuppoſe a man to pull, or preſs the end of the long arm with the force of 200 pound weight, and that the Earth contains in round numbers, 4,000,000,000,000,000,000,000, or 4000 Trillions of cubic feet, each at a mean rate weighing 100 pound: and that the prop or center of motion of the lever is 6000 miles from the Earth's center: in this caſe, the length of the lever from the *Fulcrum* or center of motion to the moving power or weight ought to be 12,000,000,000,000,000,000,000,000,000, or 12 Quadrillions of miles; and ſo many miles muſt the power move, in order to raiſe the Earth but one mile; whence it is eaſy to compute, that if ARCHIMEDES, or the power applied, could move as ſwift as a cannon-bullet, it would take 27,000,000,000,000, or 27 Billions of years to raiſe the Earth one inch.

If any other machine, ſuch as a combination of wheels and ſcrews, was propoſed to move the Earth, the time it would require, and the ſpace gone through by the hand that turned the machine, would be the ſame as before. Hence we may learn, that however boundleſs our Imagination and Theory may be, the actual operations of man are confined within narrow bounds; and more ſuited to our real wants than to our deſires.

160. The Sun and Planets mutually attract each other: the power by which they do ſo we call *Gravity*. But whether this power be mechanical or no, is very much diſputed. Obſervation proves that the Planets diſturb one another's motions by it, and that it decreaſes according to the ſquares of the diſtances of the Sun and Planets; as light, which is known to be material, likewiſe does. Hard to determine what Gravity is.

 Hence

Hence Gravity should seem to arise from the agency of some subtle matter pressing toward the Sun and Planets, and acting like all mechanical causes, by contact. But, on the other hand, when we consider that the degree or force of Gravity is exactly in proportion to the quantities of matter in those bodies, without any regard to their bulks or quantities of surface, acting as freely on their internal as external parts, it seems to surpass the power of mechanism, and to be either the immediate agency of the Deity, or effected by a law originally established and imprest on all matter by him. But some affirm that matter, being altogether inert, cannot be impressed with any Law, even by almighty Power; and that the Deity, or some subordinate intelligence, must therefore be constantly impelling the Planets toward the Sun, and moving them with the same irregularities and disturbances which Gravity would cause, if it could be supposed to exist. But, if a man may venture to publish his own thoughts, it seems to me no more an absurdity, to suppose the Deity capable of infusing a Law, or what Laws he pleases, into matter, than to suppose him capable of giving it existence at first. The manner of both is equally inconceivable to us; but neither of them imply a contradiction in our ideas: and what implies no contradiction is within the power of Omnipotence.

161. That the projectile force was at first given by the Deity is evident. For, since matter can never put itself in motion, and all bodies may be moved in any direction whatsoever; and yet the Planets, both primary and secondary, move from west to east, in planes nearly coincident; while the Comets move in all directions, and in planes very different from one another; these motions can be owing to no mechanical cause or necessity, but to the free will and power of an intelligent Being.

162. Whatever Gravity be, it is plain that it acts every moment of time: for if its action should cease, the projectile force would instantly carry off the Planets in straight lines from those parts of their Orbits where Gravity left them. But, the Planets being once put into motion, there is no occasion for any new projectile force, unless they meet with some resistance in their Orbits; nor for any mending hand, unless they disturb one another too much by their mutual attractions.

163. It is found that there are disturbances among the Planets in their motions, arising from their mutual attractions when they are in the same quarter of the Heavens; and the best modern observers find that our years are not always precisely of the same length *. Besides, there is reason to believe that the Moon is somewhat nearer the Earth now than she was formerly; her periodical month being shorter than it was in former ages. For our Astronomical Tables, which in the present Age shew the times of Solar and Lunar Eclipses to great precision, do not answer so well for very ancient Eclipses. Hence it appears, that the Moon does not move in a medium void of all resistance, § 174; and therefore her projectile force being a little weakened, while there is nothing to diminish her gravity, she must be gradually approaching nearer the Earth, describing smaller and smaller Circles round it in every Revolution, and finishing her Period sooner, although her absolute motion

The Planets disturb one another's motions.

The consequences thereof.

* If the Planets did not mutually attract one another, the areas described by them would be exactly proportionate to the times of description, § 153. But observations prove that these areas are not in such exact proportion, and are most varied when the greatest number of Planets are in any particular quarter of the Heavens. When any two Planets are in conjunction, their mutual attractions, which tend to bring them nearer to one another, draws the inferior one a little farther from the Sun, and the superior one a little nearer to him; by which means, the figure of their Orbits is somewhat altered; but this alteration is too small to be discovered in several ages.

with regard to ſpace be not ſo quick now as it was formerly: and, therefore, ſhe muſt come to the Earth at laſt; unleſs that Being, which gave her a ſufficient projectile force at the beginning, adds a little more to it in due time. And, as all the Planets move in ſpaces full of ether and light, which are material ſubſtances, they too muſt meet with ſome reſiſtance And therefore, if their gravities are not diminiſhed, nor their projectile forces increaſed, they muſt neceſſarily approach nearer and nearer the Sun, and at length fall upon and unite with him.

The world not eternal.

164. Here we have a ſtrong philoſophical argument againſt the eternity of the World. For, had it exiſted from eternity, and been left by the Deity to be governed by the combined actions of the above forces or powers, generally called Laws, it had been at an end long ago. And if it be left to them, it muſt come to an end. But we may be certain that it will laſt as long as was intended by its Author, who ought no more to be found fault with for framing ſo periſhable a work, than for making man mortal.

CHAP. VIII.

Of Light. Its proportional Quantities on the different Planets. Its Refractions in Water and Air. The Atmoſphere; its Weight and Properties. The Horizontal Moon.

165. LIGHT conſiſts of exceeding ſmall particles of matter iſſuing from a luminous body; as from a lighted candle ſuch particles of matter conſtantly flow in all directions. Dr. NIEWENTYT* computes, that in one ſecond of time there flows 418,660,000,000,000,000,000,000,000,000,000,000,000,000,000 particles of light out of a burning candle; which number contains at leaſt

The amazing ſmallneſs of the particles of light.

* Religious Philoſopher, Vol. III. p. 65.

6,337,

6,337,242,000,000 times the number of grains of ſand in the whole Earth; ſuppoſing 100 grains of ſand to be equal in length to an inch, and conſequently, every cubic inch of the Earth to contain one million of ſuch grains.

166. Theſe amazingly ſmall particles, by ſtriking upon our eyes, excite in our minds the idea of light: and, if they were as large as the ſmalleſt particles of matter diſcernible by our beſt microſcopes, inſtead of being ſerviceable to us, they would ſoon deprive us of ſight by the force ariſing from their immenſe velocity, which is above 164 thouſand miles every ſecond*, or 1,230,000 times ſwifter than the motion of a cannon-bullet. And therefore, if the particles of light were ſo large, that a million of them were equal in bulk to an ordinary grain of ſand, we durſt no more open our eyes to the light, than ſuffer ſand to be ſhot point blank againſt them.

The dreadful effects that would enſue from their being larger.

167. When theſe ſmall particles, flowing from the Sun or from a candle, fall upon bodies, and are thereby reflected to our eyes, they excite in us the idea of that body, by forming its picture on the retina†. And ſince bodies are viſible on all ſides, light muſt be reflected from them in all directions.

How objects become viſible to us.

168. A ray of light is a continued ſtream of theſe particles, flowing from any viſible body in a ſtraight line. That the rays move in ſtraight, and not in crooked lines, unleſs they be refracted, is evident from bodies not being viſible if we endeavour to look at them through the bore of a bended pipe; and from their ceaſing to be ſeen by the interpoſition of other bodies, as the fixed Stars by the interpoſition of the Moon and Planets, and the Sun wholly or in part by the interpoſition of the Moon, Mercury, or Venus. And that theſe rays do not interfere, or joſtle one another out of their

The rays of light naturally move in ſtraight lines.

A proof that they hinder not one another's motions.

* This will be demonſtrated in the eleventh Chapter.
† A fine net-work membrane in the bottom of the eye.

PLATE II. their ways, in flowing from different bodies all around, is plain from the following Experiment. Make a little hole in a thin plate of metal, and set the plate upright on a table, facing a row of lighted candles standing by one another; then place a sheet of paper or pasteboard at a little distance from the other side of the plate, and the rays of all the candles, flowing through the hole, will form as many specks of light on the paper as there are candles before the plate; each speck as distinct and large, as if there were only one candle to cast one speck; which shews that the rays are no hindrance to each other in their motions, although they all cross in the hole.

169. Light, and therefore heat, so far as it depends on the Sun's rays, (§ 85, toward the end) decreases in proportion to the squares of the distances of the Planets from the Sun. This is easily demonstrated by a Figure which, together with its description, I have taken from Dr. SMITH's Optics*. Let the light which flows from a point *A*, and passes through a square hole *B*, be received upon a plane *C*, parallel to the plane of the hole; or, if you please, let the figure *C* be the shadow of the plane *B*; and when the distance *C* is double of *B*, the length and breadth of the shadow *C* will be each double of the length and breadth of the plane *B*; and treble when *AD* is treble of *AB*; and so on: which may be easily examined by the light of a candle placed at *A*. Therefore the surface of the shadow *C*, at the distance *AC* double of *AB*, is divisible into four squares, and at a treble distance, into nine squares, severally equal to the square *B*, as represented in the Figure. The light then which falls upon the plane B, being suffered to pass to double that distance, will be uniformly spread over four times the space, and consequently will be four times thinner

Fig. XI.

In what proportion light and heat decrease at any given distance from the Sun.

* Book I. Art. 57.

in

in every part of that ſpace; and at a treble diſtance, it will be nine times thinner; and at a quadruple diſtance, ſixteen times thinner, than it was at firſt; and ſo on, according to the increaſe of the ſquare ſurfaces *B*, *C*, *D*, *E*; built upon the diſtances *AB*, *AC*, *AD*, *AE*. Conſequently, the quantities of this rarified light received upon a ſurface of any given ſize and ſhape whatever, removed ſucceſſively to theſe ſeveral diſtances, will be but one fourth, one ninth, one ſixteenth of the whole quantity received by it at the firſt diſtance *AB*. Or, in general words, the denſities and quantities of light, received upon any given plane, are diminiſhed in the ſame proportion, as the ſquares of the diſtances of that plane, from the luminous body, are increaſed: and, on the contrary, are increaſed in the ſame proportion as theſe ſquares are diminiſhed. PLATE II.

170. The more a teleſcope magnifies the diſks of the Moon and Planets, they appear ſo much dimmer than to the bare eye; becauſe the teleſcope cannot magnify the quantity of light as it does the ſurface; and, by ſpreading the ſame quantity of light over a ſurface ſo much larger than the naked eye beheld, juſt ſo much dimmer muſt it appear when viewed by a teleſcope than by the bare eye.

Why the Planets appear dimmer when viewed through teleſcopes than by the bare eye.

171. When a ray of light paſſes out of one medium * into another, it is refracted, or turned out of its firſt courſe, more or leſs, as it falls more or leſs obliquely on the refracting ſurface which divides the two mediums. This may be proved by ſeveral experiments; of which we ſhall only give three for example's ſake. 1. In a baſon *FGH*, put a piece of money, as *DB*, and then retire from it to *A*; that is, till the edge of the baſon at *E* juſt hides the money from your ſight; then keep- Fig. VIII.

* A medium, in this ſenſe, is any tranſparent body, or that through which the rays of light can paſs; as water, glaſs, diamond, air, and even a vacuum is ſometimes called a Medium.

ing

ing your head ſteady, let another perſon fill the baſon gently with water. As he fills it, you will ſee more and more of the piece *DB*; which will be all in view when the baſon is full, and appear as if lifted up to *C*. For the ray *AEB*, which was ſtraight while the baſon was empty, is now bent at the ſurface of the water in *E*, and turned out of its rectilineal courſe into the direction *ED*. Or, in other words, the ray *DEK*, that proceeded in a ſtraight line from the edge *D* while the baſon was empty, and went above the eye at *A*, is now bent at *E*; and inſtead of going on in the rectilineal direction *DEK*, goes in the angled direction *DEA*, and by entering the eye at *A* renders the object *DB* viſible. Or, 2dly, Place the baſon where the Sun ſhines obliquely, and obſerve where the ſhadow of the rim *E* falls on the bottom, as at *B*: then fill it with water, and the ſhadow will fall at *D*; which proves, that the rays of light, falling obliquely on the ſurface of the water, are refracted, or bent downwards into it.

Refraction of the rays of light.

172. The leſs obliquely the rays of light fall upon the ſurface of any medium, the leſs they are refracted; and if they fall perpendicularly on it, they are not refracted at all. For, in the laſt experiment, the higher the Sun riſes, the leſs will be the difference between the places where the edge of the ſhadow falls, in the empty and full baſon. And, 3dly, If a ſtick be laid over the baſon, and the Sun's rays being reflected perpendicularly into it from a looking-glaſs, the ſhadow of the ſtick will fall upon the ſame place of the bottom, whether the baſon be full or empty.

173. The denſer that any medium is, the more is light refracted in paſſing through it.

The Atmoſphere.

174. The Earth is ſurrounded by a thin fluid maſs of matter, called the *Air* or *Atmoſphere*, which gravitates to the Earth, revolves with it in its diurnal motion, and goes round the Sun with

it every year. This fluid is of an elaſtic or ſpringy nature, and its loweſt part, being preſſed by the weight of all the Air above it, is preſſed the cloſeſt together; and therefore the atmoſphere is denſeſt of all at the Earth's Surface, and becomes gradually rarer higher up. " It is well known* that the Air near the ſurface of our Earth poſſeſſes a ſpace about 1200 times greater than Water of the ſame weight. And therefore, a cylindric column of Air 1200 feet high, is of equal weight with a cylinder of Water of the ſame breadth, and but one foot high. But a cylinder of Air reaching to the top of the Atmoſphere is of equal weight with a cylinder of Water about 33 feet high†; and therefore, if from the whole cylinder of Air, the lower part of 1200 feet high is taken away, the remaining upper part will be of equal weight with a cylinder of Water 32 feet high; wherefore, at the height of 1200 feet, or two furlongs, the weight of the incumbent air is leſs, and conſequently the rarity of the compreſſed Air is greater than near the Earth's ſurface, in the ratio of 33 to 32. And the Air at all heights whatſoever, ſuppoſing the expanſion thereof to be reciprocally proportional to its compreſſion; and this proportion has been proved by the experiments of Dr. *Hooke* and others. The reſult of the computation I have ſet down in the annexed Table: in the firſt column of which you have the height of the Air in miles, whereof 4000 make a ſemi-diameter of the Earth; in the ſecond the compreſſion of the Air, or the incumbent weight; in the third its rarity or expanſion, ſuppoſing gravity to decreaſe in the duplicate ratio of the diſtances from the Earth's center. And the ſmall numeral figures are here uſed to ſhew what number of cyphers muſt be joined

* NEWTON'S *Syſtem of the World*, p. 120.
† This is evident from common pumps.

to

to the numbers expressed by the larger figures, as $0.^{17}1224$ for 0.000000000000000001224, and 26956^{15} for 26956000000000000000.

The Air's compression and rarity at different heights.

	Air's	
Height.	Compression.	Expansion.
0	33	. . 1
5	17.8515 . .	. . 1.84[illegible]6
10	9.6717 . .	. . 3.4151
20	2.852. . .	. .11.571
40	0.2525 . .	. 136.83
400	$0.^{17}1224$.	26956^{1}
4000	$0.^{105}4465$	73907^{102}
40000	$0.^{192}1628$	26263^{189}
400000	$0.^{210}7895$	41798^{207}
4000000	$0.^{212}9878$	33414^{209}
Infinite.	$0.^{212}9941$	54622^{209}

From the above Table it appears that the Air in proceeding upward is rarified in such manner, that a sphere of that Air which is nearest the Earth but of one inch diameter, if dilated to an equal rarefaction with that of the Air at the height of ten semi-diameters of the Earth, would fill up more space than is contained in the whole Heavens on this side the fixed Stars. And it likewise appears that the Moon does not move in a perfectly free and unresisting medium; although the Air, at a height equal to her distances, is at least 3400^{190} times thinner than at the Earth's surface; and therefore cannot resist her motion, so as to be sensible in many ages.

Its weight how found.

175. The weight of the Air, at the Earth's surface, is found by experiments made with the Air-pump; and also by the quantity of mercury that the Atmosphere balances in the barometer; in which, at a mean state, the mercury stands $29\frac{1}{2}$ inches high. And if the tube were a square inch wide, it would at that height contain $29\frac{1}{2}$ cubic inches of mercury, which is just 15 pound weight: and

and ſo much weight of air every ſquare inch of the Earth's ſurface ſuſtains; and every ſquare foot 144 times as much, becauſe it contains 144 ſquare inches. Now, as the Earth's ſurface contains, in round numbers, 200,000,000 ſquare miles, it muſt contain no leſs than 5,575,680,000,000,000 ſquare feet; which being multiplied by 2160, the number of pounds on each ſquare foot, amounts to 12,043,468,800,000,000,000 pounds, for the weight of the whole Atmoſphere. At this rate, a middle-ſized man, whoſe ſurface is about 15 ſquare feet, is preſſed by 32,400 pound weight of Air all around; for fluids preſs equally up and down, and on all ſides. But, becauſe this enormous weight is equal on all ſides, and counterbalanced by the ſpring of the Air diffuſed through all parts of our bodies, it is not in the leaſt degree felt by us.

176. Oftentimes the ſtate of the Air is ſuch, that we feel ourſelves languid and dull; which is commonly thought to be occaſioned by the Air's being foggy and heavy about us. But that the Air is then too light, is evident from the mercury's ſinking in the barometer, at which time it is generally found that the Air has not ſufficient ſtrength to bear up the vapours which compoſe the Clouds: for, when it is otherwiſe, the Clouds mount high, and the Air is more elaſtic and weighty about us, by which means it balances the internal ſpring of the Air within us, braces up our blood-veſſels and nerves, and makes us briſk and lively.

A common miſtake about the weight of the Air.

177. According to Dr. KEILL*, and other aſtronomical writers, it is entirely owing to the Atmoſphere that the Heavens appear bright in the day-time. For, without an Atmoſphere, only that part of the Heavens would ſhine in which the Sun was placed: and if we could live without Air, and ſhould turn our backs toward the Sun, the whole Heavens would appear as dark as in the

Without an Atmoſphere the Heavens would always appear dark, and we ſhould have no twilight.

* See his Aſtronomy, p. 232.

night,

PLATE II. night, and the Stars would be feen as clear as in the nocturnal fky. In this cafe, we fhould have no twilight; but a fudden tranfition from the brighteft fun-fhine to the blackeft darknefs immediately after fun-fet; and from the blackeft darknefs to the brighteft fun-fhine at fun-rifing; which would be extremely inconvenient, if not blinding, to all mortals. But, by means of the Atmofphere, we enjoy the Sun's light, reflected from the aerial particles, for fome time before he rifes and after he fets. For, when the Earth by its rotation has withdrawn our fight from the Sun, the Atmofphere being ftill higher than we, has the Sun's light imparted to it; which gradually decreafes until he has got 18 degrees below the Horizon; and then, all that part of the Atmofphere which is above us is dark. From the length of twilight, the Doctor has calculated the height of the Atmofphere (fo far as it is denfe enough to reflect any light) to be about 44 miles. But it is feldom denfe enough at two miles height to bear up the clouds.

It brings the Sun in view before he rifes, and keeps him in view after he fets.

178. The Atmofphere refracts the Sun's rays fo, as to bring him in fight every clear day, before he rifes in the Horizon; and to keep him in view for fome minutes after he has really fet below it. For, at fome times of the year, we fee the Sun ten minutes longer above the Horizon than he would be if there were no refractions: and about fix minutes every day at a mean rate.

Fig. IX.

179. To illuftrate this, let *IEK* be a part of the Earth's furface, covered with the Atmofphere *HGFC*; and let *HEO* be the fenfible Horizon * of an obferver at *E*. When the Sun is at *A*, really below the Horizon, a ray of light, *AC*, proceeding from him comes ftraight to *C*, where it falls on the furface of the Atmofphere, and there entering a denfer medium, it is turned out of its rectilineal

* As far as one can fee round him on the Earth.

courfe

courſe *ACdG*, and bent down to the obſerver's eye at *E*; who then ſees the Sun in the direction of the refracted ray *Ede*, which lies above the Horizon, and being extended out to the Heavens, ſhews the Sun at *B*, § 171.

180. The higher the Sun riſes, the leſs his rays are refracted, becauſe they fall leſs obliquely on the ſurface of the Atmoſphere, § 172. Thus, when the Sun is in the direction of the line *EfL* continued, he is ſo nearly perpendicular to the ſurface of the Earth at *E*, that his rays are but very little bent from a rectilineal courſe.

181. The Sun is about 32¼ min. of a deg. in breadth, when at his mean diſtance from the Earth; and the horizontal refraction of his rays is 33¾ min. which being more than his whole diameter, brings all his Diſc in view, when his uppermoſt edge riſes in the Horizon. At ten deg. height, the refraction is not quite 5 min.; at 20 deg. only 2 min. 26 ſec.; at 30 deg. but 1 min. 32 ſec.; and at the Zenith, it is nothing; the quantity throughout is ſhewn by the annexed Table, calculated by Sir Isaac Newton. The quantity of Refraction.

182. *A* TABLE *shewing the Refractions of the Sun, Moon, and Stars; adapted to their apparent Altitudes.*

Appar. Alt.		Refraction.		Ap. Alt.	Refraction.		Ap. Alt.	Refraction.	
D.	M.	M.	S.	D.	M.	S.	D.	M.	S.
0	0	33	45	21	2	18	56	0	36
0	15	30	24	22	2	11	57	0	35
0	30	27	35	23	2	5	58	0	34
0	45	25	11	24	1	59	59	0	32
1	0	23	7	25	1	54	60	0	31
1	15	21	20	26	1	49	61	0	30
1	30	19	46	27	1	44	62	0	28
1	45	18	22	28	1	40	63	0	27
2	0	17	8	29	1	36	64	0	26
2	30	15	2	30	1	32	65	0	25
3	0	13	20	31	1	28	66	0	24
3	30	11	57	32	1	25	67	0	23
4	0	10	48	33	1	22	68	0	22
4	30	9	50	34	1	19	69	0	21
5	0	9	2	35	1	16	70	0	20
5	30	8	21	36	1	13	71	0	19
6	0	7	45	37	1	11	72	0	18
6	30	7	14	38	1	8	73	0	17
7	0	6	47	39	1	6	74	0	16
7	30	6	22	40	1	4	75	0	15
8	0	6	0	41	1	2	76	0	14
8	30	5	40	42	1	0	77	0	13
9	0	5	22	43	0	58	78	0	12
9	30	5	6	44	0	56	79	0	11
10	0	4	52	45	0	54	80	0	10
11	0	4	27	46	0	52	81	0	9
12	0	4	5	47	0	50	82	0	8
13	0	3	47	48	0	48	83	0	7
14	0	3	31	49	0	47	84	0	6
15	0	3	17	50	0	45	85	0	5
16	0	3	4	51	0	44	86	0	4
17	0	2	53	52	0	42	87	0	3
18	0	2	43	53	0	40	88	0	2
19	0	2	34	54	0	39	89	0	1
20	0	2	26	55	0	38	90	0	0

183. In all obſervations, to have the true altitude of the Sun, Moon, or Stars, the refraction muſt be ſubtracted from the obſerved altitude. But the quantity of refraction is not always the ſame at the ſame altitude; becauſe heat diminiſhes the Air's refractive power and denſity, and cold increaſes both; and therefore no one table can ſerve preciſely for the ſame place at all ſeaſons, nor even at all times of the ſame day, much leſs for different climates; it having been obſerved that the horizontal refractions are near a third part leſs at the Equator than at *Paris*, as mentioned by Dr. SMITH in the 370th remark on his Optics, where the following account is given of an extraordinary refraction of the Sun-beams by cold. "There is a famous obſervation of this kind made by ſome *Hollanders* that wintered in *Nova Zembla* in the year 1596, who were ſurprized to find, that after a continual night of three months, the Sun began to riſe ſeventeen days ſooner than according to computation, deduced from the Altitude of the Pole obſerved to be 76°: which cannot otherwiſe be accounted for, than by an extraordinary refraction of the Sun's rays paſſing through the cold denſe air in that climate. Kepler computes that the Sun was almoſt five degrees below the Horizon when he firſt appeared; and conſequently the refraction of his rays was about nine times greater than it is with us."

PLATE II.

The inconſtancy of Refractions.

A very remarkable caſe concerning refraction.

184. The Sun and Moon appear of an oval figure, as *FCGD*, juſt after their riſing, and before their ſetting: the reaſon of which is, the refraction being greater in the Horizon than at any diſtance above it, the lower limb *G* is more elevated by it than the uppermoſt. But although the refraction ſhortens the vertical Diameter *FG*, it has no ſenſible effect on the horizontal Diameter *CD*, which is all equally elevated. When the refraction is ſo ſmall as to be imperceptible, the Sun and Moon appear perfectly round, as *AEBF*.

Fig. X.

Our imagination cannot judge rightly of the distance of inaccessible objects.

185. We daily observe, that the objects which appear most distinct are generally those which are nearest to us; and consequently, when we have nothing but our imagination to assist us in estimating of distances, bright objects seem nearer to us than those which are less bright, or than the same objects do when they appear less bright and worse defined, even though their distance in both cases be the same. And if in both cases they are seen under the same Angle*, our imagination naturally

PLATE II. Fig. V.

* An Angle is the inclination of two right lines, as *IH* and *KH*, meeting in a point at *H*; and in describing an Angle by three letters, the middle letter always denotes the angular point; thus, the above lines *IH* and *KH* meeting each other at *H*, make the Angle *IHK*; and the point *H* is supposed to be the center of a Circle, the circumference of which contains 360 equal parts, called Degrees. A fourth part of a Circle, called a Quadrant, as *GE*, contains 90 degrees; and every Angle is measured by the number of degrees in the Arc it cuts off; as the Angle *EHP* is 45 degrees, the Angle *EHF* 33, &c. and so the Angle *EHF* is the same with the Angle *CHN*, and also with the Angle *AHM*, because they all cut off the same Arc or portion of the Quadrant *EG*; but the Angle *EHF* is greater than the Angle *CHD* or *AHL*, because it cuts off a greater Arc.

The nearer an object is to the eye, the bigger it appears, and it is seen under the greater Angle. To illustrate this a little, suppose an Arrow in the position *IK*, perpendicular to the right line *HA*, drawn from the eye at *H* through the middle of the Arrow at *O*. It is plain that the Arrow is seen under the Angle *IHK*, and that *HO*, which is its distance from the eye, divides into halves both the Arrow and the Angle under which it is seen, *viz.* the Arrow into *IO*, *OK*; and the Angle into *IHO* and *KHO*: and this will be the case whatever distance the Arrow is placed at. Let now three Arrows, all of the same length with *IK*, be placed at the distances *HA*, *HC*, *HE*, still perpendicular to, and bisected by the right line *HA*; then will *AB*, *CD*, *EF*, be each equal to, and represent *OI*; and *AB* (the same as *OI*) will be seen from *H* under the Angle *AHB*; but *CD* (the same as *OI*) will be seen under the Angle *CHD*, or *AHL*; and *EF* (the same as *OI*) will be seen under the Angle *EHF*, or *CHN*, or *AHM*. Also *EF*, or *OI*, at the distance *HE*, will appear as long as *ON* would at the distance *HC*, or as *AM* would at the distance *HA*; and *CD*, or *IO*, at the distance *HC*, will appear as long as *AL* would at the distance rally ſuggeſts an idea of a greater diſtance between us and thoſe objects which appear fainter and worſe defined than thoſe which appear brighter under the ſame Angles; eſpecially if they be ſuch objects as we were never near to, and of whoſe real Magnitudes we can be no judges by ſight.

186. But, it is not only in judging of the different apparent Magnitudes of the ſame objects, which are better or worſe defined by their being more or leſs bright, that we may be deceived: for we may make a wrong concluſion even when we view them under equal degrees of brightneſs, and under equal Angles; although they be objects whoſe bulks we are generally acquainted with, ſuch as houſes or trees: for proof of which, the two following inſtances may ſuffice: Nor always of thoſe which are acceſſible.

Firſt, When a houſe is ſeen over a very broad river by a perſon ſtanding on low ground, who ſees nothing of the river, nor knows of it beforehand: the breadth of the river being hid from him, becauſe the banks ſeem contiguous, he loſes the idea of a diſtance equal to that breadth; and the houſe ſeems ſmall, becauſe he refers it to a leſs diſtance than it really is at. But, if he goes to a place from which the river and interjacent ground can be ſeen, though no farther from the houſe, he then perceives the houſe to be at a greater diſtance than he imagined; and therefore fancies it to be bigger than he did at firſt; although in both caſes it appears under the ſame angle, and conſequently makes no bigger picture on the retina of his eye in the latter caſe than it did in the former. Many have been deceived, by taking a red coat of arms fixed upon the iron gate in *Clare-Hall* walks at The reaſon aſſigned.

tance *HA*. So that as an object approaches the eye, both its Magnitude and the Angle under which is is ſeen increaſe; and the contrary as the object recedes.

PLATE II. *Cambridge*, for a brick houfe at a much greater diftance*.

Secondly, In foggy weather, at firft fight, we generally imagine a fmall houfe, which is juft at hand, to be a great caftle at a diftance; becaufe it appears fo dull and ill-defined when feen through the Mift, that we refer it to a much greater diftance than it really is at; and therefore, under the fame Angle, we judge it to be much bigger. For Fig. XII. the near object *FE*, feen by the eye *ABD*, appears under the fame Angle *GCH* that the remote object *GHI* does: and the rays *GFCN* and *HECM*, croffing one another at *C* in the pupil of the eye, limit the fize of the picture *MN* on the retina, which is the picture of the object *FE*; and if *FE* were taken away, would be the picture of the object *GHI*, only worfe defined; becaufe *GHI* being farther off, appears duller and fainter than *FE* did. But when a Fog, as *KL*, comes between the eye and the object *FE*, the object appears dull and ill-defined like *GHI*; which caufes our imagination to refer *FE* to the greater diftance *CH*, inftead of the fmall diftance *CE*, which it really is at. And confequently, as mif-judging the diftance does not in the leaft diminifh the Angle under which the object appears, the fmall hay-rick *FE* feems to be as big as *GHI*.

* The fields which are beyond the gate rife gradually till they are juft feen over it; and the arms being red, are often miftaken for a houfe at a confiderable diftance in thofe fields.

I once met with a curious deception in a gentleman's garden at *Hackney*, occafioned by a large pane of glafs in the garden-wall at fome diftance from his houfe. The glafs (through which the fky was feen from low ground) reflected a very faint image of the Houfe; but the image feemed to be in the Clouds near the Horizon, and at that diftance looked as if it were a huge caftle in the Air. Yet the Angle, under which the image appeared, was equal to that under which the houfe was feen: but the image being mentally referred to a much greater diftance than the houfe, appeared much bigger to the imagination.

187. The

187. The Sun and Moon appear bigger in the Horizon than at any considerable height above it. These Luminaries, although at great distances from the Earth, appear floating, as it were, on the surface of our Atmosphere *HGFfeC*, a little way beyond the Clouds; of which, those about *F*, directly over our heads at *E*, are nearer us than those about *H* or *e* in the Horizon *HEe*. Therefore, when the Sun or Moon appear in the Horizon at *e*, they are not only seen in a part of the Sky which is really farther from us than if they were at any considerable Altitude, as about *f*; but they are also seen through a greater quantity of Air and Vapours at *e* than at *f*. Here we have two concurring appearances which deceive our imagination, and cause us to refer the Sun and Moon to a greater distance at their rising or setting about *e*, than when they are considerably high, as at *f*: first, their seeming to be on a part of the Atmosphere at *e*, which is really farther than *f* from a spectator at E; and secondly, their being seen through a grosser medium, when at *e*, than when at *f*; which, by rendering them dimmer, causes us to imagine them to be at a yet greater distance. And as, in both cases, they are seen * much under the same Angle, we naturally judge them to be biggest when they seem farthest from us; like the above-mentioned house, § 186, seen from a higher ground, which shewed it to be farther off than it appeared from low ground, or the hay-rick, which appeared at a greater distance by means of an interposing Fog. PLATE II. Fig. IX. Why the Sun and Moon appear biggest in the Horizon.

188. Any one may satisfy himself that the Moon appears under no greater Angle in the Horizon than on the Meridian, by taking a large sheet of paper, and rolling it up in the form of a Tube, of such a width, that observing the Moon through Their apparent Diameters are not less on the Meridian than in the Horizon.

* The Sun and Moon subtend a greater Angle on the Meridian than in the Horizon, being nearer the Observer's Place in the former case than in the latter.

it when she rises, she may, as it were, just fill the Tube; then tie a thread round it to keep it of that size; and when the Moon comes to the Meridian, and appears much less to the eye, look at her again through the same Tube, and she will fill it just as much, if not more, than she did at her rising.

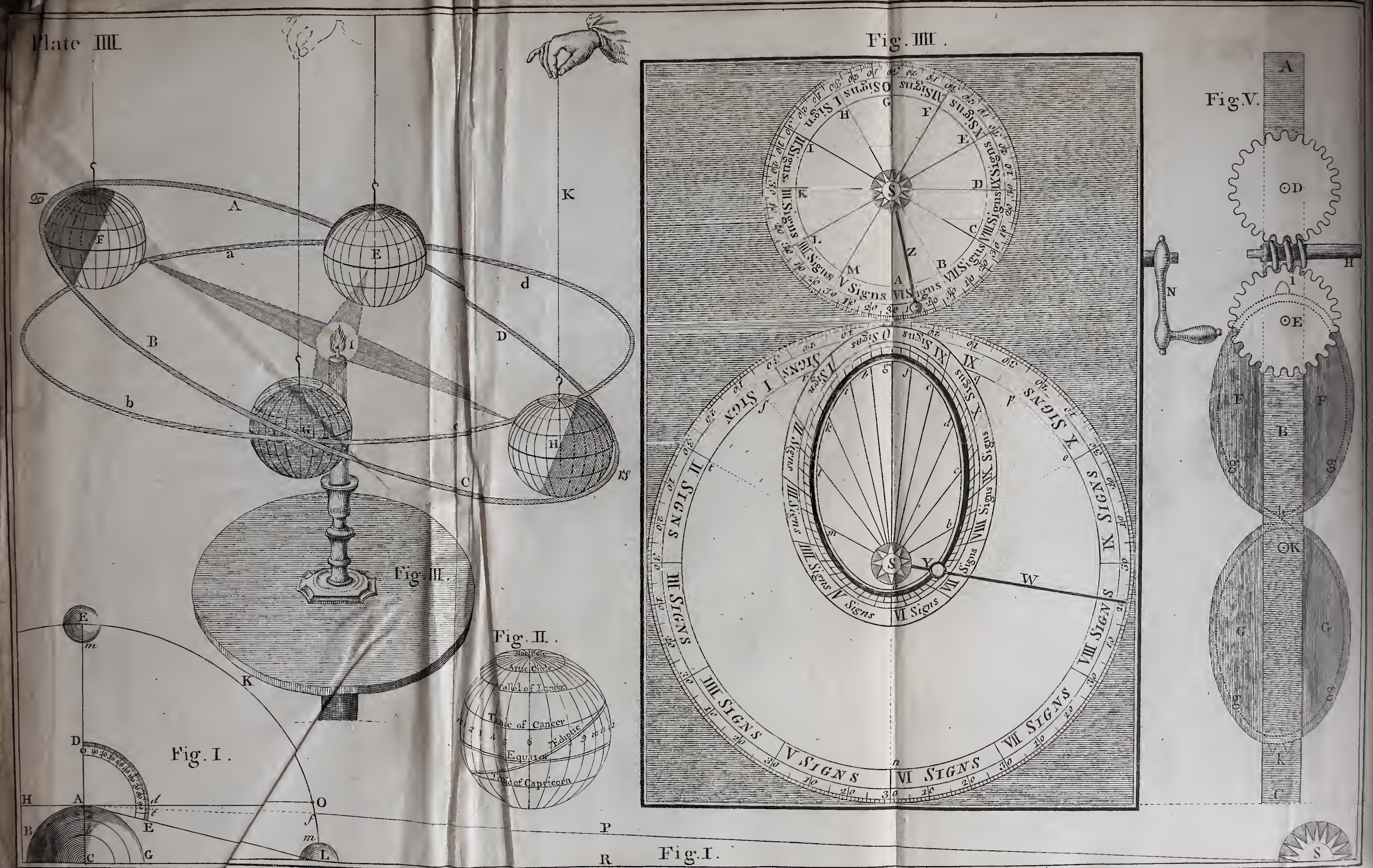
189. When the full Moon is in *perigee*, or at her least distance from the Earth, she is seen under a larger Angle, and must therefore appear bigger than when she is full at other times; and if that part of the Atmosphere where she rises be more replete with Vapours than usual, she appears so much the dimmer; and therefore we fancy her to be still the bigger, by referring her to an unusually great distance, knowing that no objects which are very far distant can appear big unless they be really so.

CHAP. IX.

The Method of finding the Distances of the Sun Moon, and Planets.

190. THOSE who have not learnt how to take the * Altitude of any Celestial Phenomenon by a common Quadrant, nor know any

* The Altitude of any celestial Object is an arc of the Sky intercepted between the Horizon and the Object. In Fig. VI. of Plate II. let *HOX* be a horizontal line, supposed to be extended from the eye at *A* to *X*, where the Sky and Earth seem to meet at the end of a long and level plain; and let *S* be the Sun. The arc *XY* will be the Sun's height above the Horizon at *X*, and is found by the instrument *ECD*, which is a quadrantal board, or plate of metal, divided into 90 equal parts or degrees on its limb *DPC*, and has a couple of little brass plates, as *a* and *b*, with a small hole in each of them, called *Sight-Holes*, for looking through, parallel to the edge of the Quadrant which they stand on. To the center *E* is fixed one end of a thread *F*, called the *Plumb-Line*, which has a small weight or plummet *P* fixed to its other end. Now, if an observer holds the Quadrant upright, without inclining it to either



J. Ferguson delin. J. Mynde Sculp.

any thing of plain Trigonometry, may paſs over the firſt Article of this ſhort Chapter, and take the Aſtronomer's word for it, that the diſtances of the Sun and Planets are as ſtated in the firſt Chapter of this Book. But, to every one who knows how to take the Altitude of the Sun, the Moon, or a Star, and can ſolve a plain right-angled Triangle, the following method of finding the diſtances of the Sun and Moon will be eaſily underſtood. PLATE IV.

Let *BAG* be one half of the Earth, *AC* its ſemi-diameter, *S* the Sun, *m* the Moon, and *EKOL* a quarter of the Circle deſcribed by the Moon in revolving from the Meridian to the Meridian again. Let *CRS* be the rational Horizon of an obſerver at *A*, extended to the Sun in the Heavens; and *HAO* his ſenſible Horizon, extended to the Moon's Orbit. *ALC* is the Angle under which the Earth's ſemi-diameter *AC* is ſeen from the Moon at *L*, which is equal to the Angle *OAL*, becauſe the right lines *AO* and *CL*, which include both theſe Angles, are parallel. *ASC* is the Angle Fig. I.

either ſide, and ſo that the Horizon at *X* is ſeen through the ſight-holes *a* and *b*, the plumb-line will cut or hang over the beginning of the degrees at 0, in the edge *EC*; but if he elevates the Quadrant ſo as to look through the ſight-holes at any part of the Heavens, ſuppoſe the Sun at *S*, juſt ſo many degrees as he elevates the ſight-hole *b* above the horizontal line *HOX*, ſo many degrees will the plumb-line cut in the limb *CP* of the Quadrant. For, let the obſerver's eye at *A* be in the center of the celeſtial Arc *XYV* (and he may be ſaid to be in the center of the Sun's apparent diurnal Orbit, let him be on what part of the Earth he will) in which Arc the Sun is at that time, ſuppoſe 25 degrees high, and let the obſerver hold the Quadrant ſo that he may ſee the Sun through the ſight holes; the plumb-line freely playing on the Quadrant will cut the 25th degree in the limb *CP*, equal to the number of degrees of the Sun's Altitude at the time of obſervation. *N. B.* Whoever looks at the Sun muſt have a ſmoked glaſs before his eyes to ſave them from hurt. The better way is not to look at the Sun through the ſight-holes, but to hold the Quadrant facing the eye at a little diſtance, and ſo that the Sun ſhining through one hole, the ray may be ſeen to fall on the other.

under which the Earth's ſemi-diameter *AC* is ſeen from the Sun at *S*, and is equal to the Angle *OAf*, becauſe the lines *AO* and *CRS* are parallel. Now it is found by obſervation, that the Angle *OAL* is much greater than the Angle *OAf*; but *OAL* is equal to *ALC*, and *OAf* is equal to *ASC*. Now, as *ASC* is much leſs than *ALC*, it proves that the Earth's ſemi-diameter *AC* appears much greater as ſeen from the Moon at *L*, than from the Sun at *S*; and therefore the Earth is much farther from the Sun than from the Moon*. The Quantities of theſe Angles may be determined by obſervation in the following manner:

Let a graduated inſtrument, as *DAE*, (the larger the better) having a moveable Index with Sight-holes, be fixed in ſuch a manner, that its plane ſurface may be parallel to the plane of the Equator, and its edge *AD* in the plane of the Meridian: ſo that when the Moon is in the Equinoctial, and on the Meridian *ADE*, ſhe may be ſeen through the ſight-holes when the edge of the moveable Index cuts the beginning of the diviſions at o, on the graduated limb *DE*; and when ſhe is ſo ſeen, let the *preciſe* time be noted. Now, as the Moon revolves about the Earth from the Meridian to the Meridian again in about 24 hours 48 minutes, ſhe will go a fourth part round it in a fourth part of that time, *viz.* in 6 hours 12 minutes, as ſeen from *C*, that is, from the Earth's center or pole. But as ſeen from *A*, the obſerver's place on the Earth's ſurface, the Moon will ſeem to have gone a quarter round the Earth when ſhe comes to the ſenſible Horizon at *O*; for the Index through the ſights of which ſhe is then viewed will be at *d*, 90 degrees from *D*, where it was when ſhe was ſeen at *E*. Now, let the exact moment when the Moon is ſeen at *O* (which will be when ſhe is in or near

* See the Note on § 185.

the

the ſenſible Horizon) be carefully noted*, that it may be known in what time ſhe has gone from *E* to *O*; which time ſubtracted from 6 hours 12 minutes (the time of her going from *E* to *L*) leaves the time of her going from *O* to *L*, and affords an eaſy method for finding the Angle *OAL* (called *the Moon's Horizontal Parallax*, which is equal to the Angle *ALC*) by the following Analogy: As the time of the Moon's deſcribing the Arc *EO* is to 90 degrees, ſo is 6 hours 12 minutes to the degrees of the Arc *Dde*, which meaſures the Angle *EAL*; from which ſubtract 90 degrees, and there remains the Angle *OAL*, equal to the Angle *ALC*, under which the Earth's ſemi-diameter *AC* is ſeen from the Moon. Now, ſince all the Angles of a right-lined Triangle are equal to 180 degrees, or to two right Angles, and the ſides of a Triangle are always proportionable to the Sines of the oppoſite Angles, ſay, by the *Rule of Three*, as the Sine of the Angle *ALC*, at the Moon *L*, is to its oppoſite ſide *AC*, the Earth's ſemi-diameter, which is known to be 3985 miles, ſo is Radius, *viz.* the Sine of 90 degrees, or of the right Angle *ALC*, to its oppoſite ſide *AD*, which is the Moon's diſtance at *L* from the obſerver's place at *A* on the Earth's ſurface; or, ſo is the Sine of the Angle *CAL* to its oppoſite ſide *CL*, which is the Moon's diſtance from the Earth's center, and comes out at a mean rate to be 240,000 miles. The Angle *CAL* is equal to what *OAL* wants of 90 degrees.

The Moon's horizontal Parallax, what.

The Moon's diſtance determined.

191. The Sun's diſtance from the Earth might be found the ſame way, though with more difficulty, if his horizontal Parallax, or the Angle *OAS*, equal to the Angle *ASC*, were not ſo ſmall, as to be hardly perceptible, being ſcarce 10 ſeconds of a minute, or the 360th part of a degree. But

The Sun's diſtance cannot be yet ſo exactly determined as the Moon's.

* Here proper allowance muſt be made for the Refraction, which being about 34 minutes of a degree in the Horizon, will cauſe the Moon's center to appear 34 minutes above the Horizon when her center is really in it.

the

the Moon's horizontal Parallax, or Angle *OAL*, equal to the Angle *ALC*, is very diſcernible, being 57′ 18″, or 3438″ at its mean ſtate; which is more than 340 times as great as the Sun's: and, therefore, the diſtances of the heavenly bodies being inverſely as the Tangents of their horizontal Parallaxes, the Sun's diſtance from the Earth is at leaſt 340 times as great as the Moon's; and is rather under-rated at 81 millions of miles, when the Moon's diſtance is certainly known to be 240 thouſand. But becauſe, according to ſome Aſtronomers, the Sun's horizontal Parallax is 11 ſeconds, and according to others only 10, the former Parallax making the Sun's diſtance to be about 75,000,000 of miles, and the latter 82,000,000; we may take it for granted, that the Sun's diſtance is not leſs than as deduced from the former, nor more than as ſhewn by the latter: and every one, who is accuſtomed to make ſuch obſervations, knows how hard it is, if not impoſſible, to avoid an error of a ſecond; eſpecially on account of the inconſtancy of horizontal Refractions. And here the error of one ſecond, in ſo ſmall an Angle, will make an error of 7 millions of miles in ſo great a diſtance as that of the Sun's. But Dr. HALLEY has ſhewn us how the Sun's diſtance from the Earth, and conſequently the diſtances of all the Planets from the Sun, may be known to within a 500th part of the whole, by a Tranſit of Venus over the Sun's Diſc, which will happen on the 6th of *June*, in the year 1761; till which time we muſt content ourſelves with allowing the Sun's diſtance to be about 81 millions of miles, as commonly ſtated by Aſtronomers.

How near the truth it may ſoon be determined.

The Sun proved to be much bigger than the Moon.

192. The Sun and Moon appear much about the ſame bulk: And every one who underſtands Geometry, knows how their true bulks may be deduced from the apparent, when their real diſtances are known. Spheres are to one another as the Cubes of their Diameters; whence, if the Sun be

be 81 millions of miles from the Earth, to appear as big as the Moon, whoſe diſtance does not exceed 240 thouſand miles, he muſt, in ſolid bulk, be 42 millions 875 thouſand times as big as the Moon.

193. The horizontal Parallaxes are beſt obſerved at the Equator; 1. Becauſe the heat is ſo nearly equal every day, that the Refractions are almoſt conſtantly the ſame. 2. Becauſe the parallactic Angle is greater there, (as at *A* the diſtance from thence to the Earth's Axis being greater), than upon any parallel of Latitude, as *a* or *b*.

194. The Earth's diſtance from the Sun being determined, the diſtances of all the other Planets from him are eaſily found by the following analogy, their periods round him being aſcertained by obſervation. As the ſquare of the Earth's period round the Sun is to the cube of its diſtance from the Sun, ſo is the ſquare of the period of any other Planet to the cube of its diſtance, in ſuch parts or meaſures as the Earth's diſtance was taken; ſee § 111. This proportion gives the relative mean diſtances of the Planets from the Sun to the greateſt degree of exactneſs; and they are as follows, having been deduced from their periodical times, according to the law juſt mentioned, which was diſcovered by KEPLER, and demonſtrated by Sir ISAAC NEWTON *.

The relative diſtances of the Planets from the Sun are known to great preciſion, though their real diſtances are not well known.

* All the following calculations on the next page, except thoſe in the two laſt lines before § 195, were printed in former editions of this work, before the year 1761. Since that time, the ſaid two lines (as found by the Tranſit A. D. 1761) were added; and alſo § 195.

Periodical Revolutions to the ſame fixed Star in days and decimal parts of a day.

Mercury	Venus	The Earth	Mars	Jupiter	Saturn	Georgian
87.9692	224 6176	365.2564	686.9785	4332.514	1079.275	30456.07

Relative mean diſtances from the Sun.

38710	72333	100000	152369	520096	954006	1908580

From theſe numbers we deduce, that if the Sun's horizontal Parallax be 10″, the real mean diſtances of the Planets from the Sun in Engliſh Miles are

31,742,200	59,313,060	82,000,000	124,942,680	426,478,720	782,284,920	1,565,035,600

But if the Sun's Parallax be 11″, their diſtances are no more than

29,032,500	54,238,570	75,000,000	114,276,750	390,034,500	715,504,500	1,431,435,000

Errors in diſtance ariſing from the miſtake of 1″ in the Sun's Parallax.

2,709,700	5,074,490	7,000,000	10,665,830	36,444,220	66,780.420	133,600,600

But, from the late Tranſit of Venus, A. D. 1761, the Sun's Parallax appears to be only 8′$\frac{65}{100}$; and according to that, their real diſtances in miles are

36,841,468	68,891,486	95,173,127	145.014 148	494 990,976	907,956.130	1,816,455,526

And their diameters, in miles, are

3100	9360	7970	5150	94,100	77,990	35,226

195. Theſe numbers ſhew, that although we have the relative diſtances of the Planets from the Sun to the greateſt nicety, yet the beſt obſervers could not aſcertain their true diſtances until the late long-wiſhed-for Tranſit appeared, in 1761, which we muſt confeſs was embarraſſed with ſeveral difficulties. But another Tranſit of Venus over the Sun has now been obſerved, on the third of *June* 1769, much better ſuited to the reſolution of this great Problem than that in 1761 was; and the reſult of the obſervations does not differ materially from the reſult of thoſe in 1761. Another tranſit will not happen till the year 1874.

196. The Earth's Axis produced to the Stars, being carried parallel * to itſelf during the Earth's annual revolution, deſcribes a circle in the Sphere of the fixed Stars equal to the Orbit of the Earth.

* By this is meant, that if a line be ſuppoſed to be drawn parallel to the Earth's Axis in any part of its Orbit, the Axis keeps parallel to that line in every other part of its Orbit: as in Fig. I. of Plate V. where *abcdefgh* repreſents the Earth's Orbit in an oblique view, and *Ns* the Earth's Axis keeping always parallel to the line *MN*.

But

But this Orbit, though very large, would seem no bigger than a point if it were viewed from the Stars; and consequently the circle described in the Sphere of the Stars by the Axis of the Earth, produced, if viewed from the Earth, must appear but as a point; that is, its diameter appears too little to be measured by observation: for Dr. Bradley has assured us, that if it had amounted to a single second, or two at most, he should have perceived it in the great number of observations he has made, especially upon γ *Draconis*; and that it seemed to him very probable that the annual Parallax of this Star is not so great as a single second; and, consequently, that it is above 400 thousand times farther from us than the Sun. Hence the celestial poles seem to continue in the same points of the Heavens throughout the year; which by no means disproves the Earth's annual motion, but plainly proves the distance of the Stars to be exceeding great.

Why the celestial Poles seem to keep still in the same points of the Heavens, notwithstanding the Earth's motion round the Sun.

197. The small apparent motion of the Stars, § 113, discovered by that great Astronomer, he found to be no ways owing to their annual Parallax (for it came out contrary thereto), but to the Aberration of their light, which can result from no known cause besides that of the Earth's annual motion; and as it agrees so exactly therewith, it proves, beyond dispute, that the Earth has such a motion: for this Aberration completes all its various Phenomena every year; and proves that the velocity of star-light is such as carries it through a space equal to the Sun's distance from us in 8 minutes 13 seconds of time. Hence the velocity of Light is * 10 thousand 210 times as great as the Earth's velocity in its Orbit; which velocity (from what we know already of the Earth's distance from the Sun) may be asserted to be at least between 57 and 58 thousand miles every hour: and supposing it to be 58000, this number multiplied by 10210, gives 592 million 180 thousand miles for

The amazing velocity of light.

* Smith's Optics, § 1157.

the

PLATE IV. the hourly motion of Light: which laſt number divided by 3600, the number of ſeconds in an hour, ſhews that Light flies at the rate of more than 164 thouſands miles every ſecond of time, or ſwing of a common clock pendulum.

CHAP. X.

The Circles of the Globe deſcribed. The different lengths of days and nights, and the viciſſitudes of ſeaſons explained. The explanation of the Phenomena of Saturn's Ring concluded. (See § 81 and 82.)

Circles of the Sphere. 198. IF the reader be hitherto unacquainted with the principal circles of the Globe, he ſhould now learn to know them; which he may do ſufficiently for this preſent purpoſe in a quarter of an hour, if he ſets the ball of a terreſtrial Globe before him, or looks at the Figure of it, wherein (Fig. II.) theſe circles are drawn and named. The *Equator* is that great circle which divides the northern half of the Earth from the ſouthern. The *Tropics* are leſſer circles parallel to the Equator, and each of them is 23½ degrees from it; a degree in this ſenſe being the 360th part of any great circle which divides the Earth into two equal parts. The *Tropic of Cancer* lies on the north ſide of the Equator, and the *Tropic of Capricorn* on the ſouth. The *Arctic Circle* has the *North Pole* for its center, and is juſt as far from the North Pole as the Tropics are from (Equator, Tropics, Polar Circles, and Poles.) the Equator: and the *Antarctic Circle* (hid by the ſuppoſed convexity of the figure) is juſt as far from the *South Pole* every way round it. Theſe Poles are the very north and ſouth points of the Globe: (Fig. II.) and all other places are denominated *northward* or *ſouthward*, according to the ſide of the Equator they lie on, and the Pole to which they are neareſt. The *Earth's Axis* is a ſtraight line paſſing through (Earth's Axis.) the center of the Earth, perpendicular to the Equator, and terminating in the Poles at its ſurface. This, in the real Earth and Planets, is only an

PLATE IV.

an imaginary line; but in artificial Globes or Planets it is a wire by which they are ſupported, and turned round in *Orreries*, or ſuch like machines; by wheel-work. The circles 12. 1. 2. 3. 4. &c. are Meridians to all places they paſs through; and we muſt ſuppoſe thouſands more to be drawn, becauſe every place, that is ever ſo little to the eaſt or weſt of any other place, has a different Meridian from that other place. All the Meridians meet in the poles; and whenever the Sun's center is paſſing over any Meridian in his apparent motion round the Earth, it is mid-day or noon to all places on that Meridian. Meridians.

199. The *broad Space* lying between the Tropics, like a girdle ſurrounding the Globe, is called the *torrid Zone*, of which the Equator is in the middle all around. The *Space* between the Tropic of Cancer and Arctic Circle is called the *North temperate Zone*. *That* between the Tropic of Capricorn and the Antarctic Circle, the *South temperate Zone*. And the two *circular Spaces* bounded by the Polar Circles are the two *frigid Zones*; denominated *north* or *ſouth*, from that Pole which is in the center of the one or the other of them. Zones.

200. Having acquired this eaſy branch of knowledge, the learner may proceed to make the following experiment with his terreſtrial ball; which will give him a plain idea of the diurnal and annual motions of the Earth, together with the different lengths of days and nights, and all the beautiful variety of ſeaſons, depending on thoſe motions.

Take about ſeven feet of ſtrong wire, and bend it into a circular form, as *abcd*, which being viewed obliquely, appears elliptical as in the Figure. Place a lighted candle on a table, and having fixed one end of a ſilk thread *K*, to the north pole of a ſmall terreſtrial Globe *H*, about three inches diameter, cauſe another perſon to hold the wire circle, ſo that it may be parallel to the table, and

Fig. III. A pleaſing experiment, ſhewing the different lengths of days and nights, and the variety of ſeaſons.

as high as the flame of the candle *I*, which ſhould be in or near the center. Then, having twiſted the thread as toward the left hand, that by untwiſting it may turn the Globe round eaſtward, or contrary to the way that the hands of a watch move, hang the Globe by the thread within this circle, almoſt contiguous to it; and as the thread untwiſts, the Globe (which is enlightened half round by the candle as the Earth is by the Sun) will turn round its Axis, and the different places upon it will be carried through the light and dark Hemiſpheres, and have the appearance of a regular ſucceſſion of days and nights, as our Earth has in reality by ſuch a motion. As the Globe turns, move your hand ſlowly, ſo as to carry the Globe round the candle according to the order of the letters *abcd*, keeping its center even with the wire circle; and you will perceive, that the candle, being ſtill perpendicular to the Equator, will enlighten the Globe from pole to pole in its whole motion round the circle; and that every place on the Globe goes equally through the light and the dark, as it turns round by the untwiſting of the thread, and therefore has a perpetual Equinox. The Globe thus turning round repreſents the Earth turning round its Axis; and the motion of the Globe round the candle repreſents the Earth's annual motion round the Sun, and ſhews, that if the Earth's Orbit had no inclination to its Axis, all the days and nights of the year would be equally long, and there would be no different ſeaſons. But now, deſire the perſon who holds the wire to hold it obliquely in the poſition *ABCD*, raiſing the ſide ♋ juſt as much as he depreſſes the ſide ♑, that the flame may be ſtill in the plane of the circle; and twiſting the thread as before, that the Globe may turn round its Axis the ſame way as you carry it round the candle, that is, from weſt to eaſt, let the Globe down into the lowermoſt part of the wire circle at ♑, and if the circle be properly inclined, the candle will ſhine perpendi-cularly

cularly on the Tropic of Cancer, and the *frigid Zone*, lying within the *arctic* or *north polar Circle*, will be all in the light, as in the Figure; and will keep in the light let the Globe turn round its Axis ever ſo often. From the Equator to the north polar Circle all the places have longer days and ſhorter nights; but from the Equator to the ſouth polar circle juſt the reverſe. The Sun does not ſet to any part of the north frigid Zone, as ſhewn by the candle's ſhining on it, ſo that the motion of the Globe can carry no place of that Zone into the dark: and at the ſame time the *ſouth frigid Zone* is involved in darkneſs, and the turning of the Globe brings none of its places into the light. If the Earth were to continue in the like part of its Orbit, the Sun would never ſet to the inhabitants of the north frigid Zone, nor riſe to thoſe of the ſouth. At the Equator it would be always equal day and night; and as places are gradually more and more diſtant from the Equator, toward the arctic Circle, they would have longer days and ſhorter nights; while thoſe on the ſouth ſide of the Equator would have their nights longer than their days. In this caſe there would be continual ſummer on the north ſide of the Equator, and continual winter on the ſouth ſide of it. Summer Solſtice.

But as the Globe turns round its Axis, move your hand ſlowly forward, ſo as to carry the Globe from *H* toward *E*, and the boundary of light and darkneſs will approach toward the north Pole, and recede from the ſouth Pole; the northern places will go through leſs and leſs of the light, and the ſouthern places through more and more of it; ſhewing how the northern days decreaſe in length, and the ſouthern days increaſe, while the Globe proceeds from *H* to *E*. When the Globe is at *E*, it is at a mean ſtate between the loweſt and higheſt parts of its Orbit; the candle is directly over the Equator, the boundary of light and darkneſs juſt reaches to both the Poles, and Autumnal Equinox.

all places on the Globe go equally through the light and dark Hemifpheres, fhewing that the days and nights are then equal at all places of the Earth, the Poles only excepted; for the Sun is then fetting to the north Pole, and rifing to the fouth Pole.

Continue moving the Globe forward, and as it goes through the quarter *A*, the north Pole recedes ftill farther into the dark Hemifphere, and the fouth Pole advances more into the light, as the Globe comes nearer to ♋: and when it comes there at *F*, the candle is directly over the Tropic of Capricorn, the days are at the fhorteft, and nights at the longeft, in the northern Hemifphere, all the way from the Equator to the arctic Circle; and the reverfe in the fouthern Hemifphere from the Equator to the antarctic circle; within which Circles it is dark to the north frigid Zone, and light to the fouth.

Winter Solftice.

Continue both motions, and as the Globe moves through the quarter *B*, the north Pole advances toward the light, and the fouth Pole toward the dark; the days lengthen in the northern Hemifphere, and fhorten in the fouthern; and when the Globe comes to *G*, the candle will be again over the Equator (as when the Globe was at *E*), and the days and nights will again be equal as formerly; and the north Pole will be juft coming into the light, the fouth Pole going out of it.

Vernal Equinox.

Thus we fee the reafon why the days lengthen and fhorten from the Equator to the polar Circles every year; why there is fometimes no day or night for many turnings of the Earth, within the polar Circles; why there is but one day and one night in the whole year at the Poles; and why the days and nights are equally long all the year round at the Equator, which is always equally cut by the circle bounding light and darknefs.

201. The

201. The inclination of an Axis or Orbit is merely relative, becauſe we compare it with ſome other Axis or Orbit which we conſider as not inclined at all. Thus, our Horizon being level to us, whatever place of the Earth we are upon, we conſider it as having no inclination; and yet, if we travel 90 degrees from that place, we ſhall then have a Horizon perpendicular to the former; but it will ſtill be level to us. And if this book be held ſo that the* Circle *ABCD* be parallel to the Horizon, both the Circle *abcd*, and the Thread or Axis *K*, will be inclined to it. But if the Book or Plate be held ſo that the Thread be perpendicular to the Horizon, then the Orbit *ABCD* will be inclined to the Thread, and the Orbit *abcd* perpendicular to it, and parallel to the Horizon. We generally conſider the Earth's annual Orbit as having no inclination, and the Orbits of all the other Planets as inclined to it, § 20. Remark. Fig. III.

202. Let us now take a view of the Earth in its annual courſe round the Sun, conſidering its Orbit as having no inclination, and its Axis as inclining 23½ degrees from a line perpendicular to the plane of its Orbit, and keeping the ſame oblique direction in all parts of its annual courſe; or, as commonly termed, keeping always parallel to itſelf, § 196.

Let *a*,*b*,*c*,*d*,*e*,*f*,*g*,*h* be the Earth in eight different parts of its Orbit, equidiſtant from one another; *Ns* its Axis, *N* its north Pole, *s* its ſouth Pole, and *S* the Sun nearly in the center of the Earth's Orbit, § 18. As the earth goes round the Sun PLATE V. Fig. 1.

* All Circles appear elliptical in an oblique view, as is evident by looking obliquely at the rim of a baſon. For the true figure of a Circle can only be ſeen when the eye is directly over its center. The more obliquely it is viewed, the more elliptical it appears, until the eye be in the ſame plane with it, and then it appears like a ſtraight line.

 according

PLATE V. according to the order of the letters *a b c d*, &c. its Axis *N s* keeps the ſame obliquity, and is ſtill parallel to the line *M N s*. When the Earth is at *a*, its north pole inclines toward the Sun *S*, and brings all the northern places more into the light than at any other time of the year. But when the Earth is at *e* in the oppoſite time of the year, the north Pole declines from the Sun, which occaſions the northern places to be more in the dark than in the light; and the reverſe at the ſouthern places, as is evident by the Figure, which I have taken from Dr. LONG's Aſtronomy. When the Earth is either at *c* or *g*, its Axis inclines not either to or from the Sun, but lies ſidewiſe to him; and then the Poles are in the boundary of light and darkneſs; and the Sun, being directly over the Equator, makes equal day and night at all places. When the Earth is at *b*, it is half-way between the Summer Solſtice and Harveſt Equinox; when it is at *d*, it is half-way from the Harveſt Equinox to the Winter Solſtice; at *f*, half-way from the Winter Solſtice to the Spring Equinox: and at *h*, half-way from the Spring Equinox to the Summer Solſtice.

A conciſe view of the ſeaſons.

Fig. II.

203. From this oblique view of the Earth's Orbit, let us ſuppoſe ourſelves to be raiſed far above it, and placed juſt over its center *S*, looking down upon it from its north Pole; and as the Earth's Orbit differs but very little from a Circle, we ſhall have its figure in ſuch a view repreſented by the Circle *ABCDEFGH*. Let us ſuppoſe this Circle to be divided into 12 equal parts, called *Signs*, having their names affixed to them; and each Sign into 30 equal parts, called *Degrees*, numbered 10, 20, 30, as in the outermoſt Circle of the Figure, which repreſents the great Ecliptic in the Heavens. The Earth is ſhewn in eight different poſitions in this Circle, and in each poſition *Æ* is the Equator, *T* the Tropic of Cancer, the *dotted*

The ſeaſons ſhewn in another view of the Earth and its Orbit.

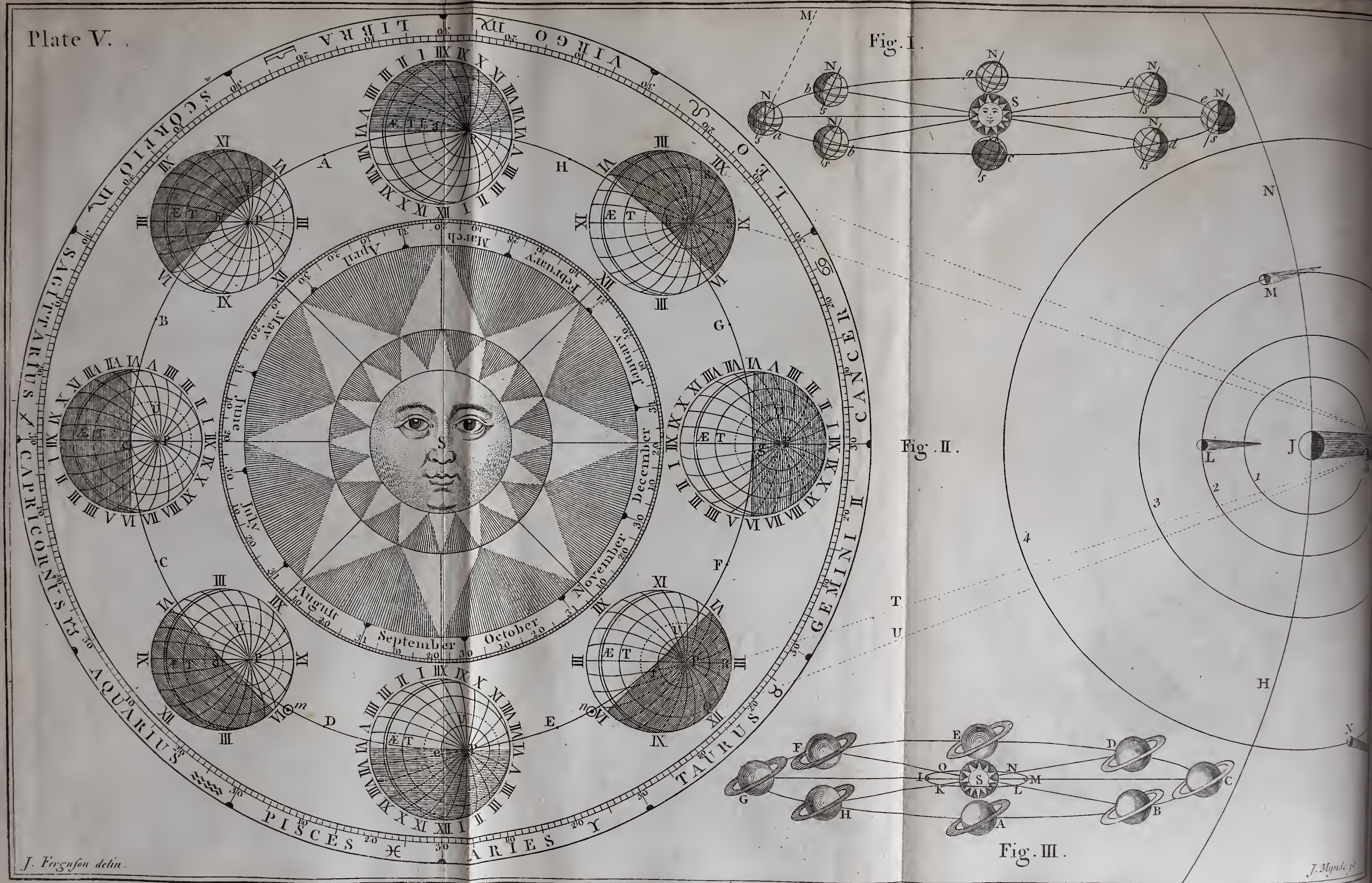


Plate V.
Fig. I.
Fig. II.
Fig. III.
LIBRA
VIRGO
LEO
CANCER
GEMINI
TAURUS
ARIES
PISCES
AQUARIUS
CAPRICORNUS
SAGITTARIUS
SCORPIO
March
April
May
June
July
August
September
October
November
December
January
February
J. Ferguson delin.
J. Mynde sc.

Circle the parallel of *London*, *U* the arctic or north polar Circle, and *P* the north Pole, where all the Meridians or Hour-Circles meet, § 198. As the Earth goes round the Sun, the north Pole keeps constantly toward one part of the Heavens, as it does in the figure toward the right-hand side of the Plate.

When the Earth is at the beginning of Libra, namely, on the 20th of *March*, in this Figure (as at *g* in Fig. I.) the Sun *S*, as seen from the Earth, appears at the beginning of Aries, in the opposite part of the Heavens *, the north Pole is just coming into the light, and the Sun is vertical to the Equator; which, together with the Tropic of Cancer, parallel of *London*, and arctic Circle, are all equally cut by the Circle bounding light and darkness, coinciding with the six-o'clock Hour-Circle, and therefore the days and nights are equally long at all places: for every part of the Meridians *ÆTLa* comes into the light at six in the morning, and revolving with the Earth according to the order of the hour-letters, goes into the dark at six in the evening. There are 24 Meridians or Hour-Circles drawn on the Earth in this Figure, to shew the Time of Sun rising and setting at different Seasons of the year. Vernal Equinox.

As the Earth moves in the Ecliptic according to the order of the letters *ABCD*, &c. through the Signs Libra, Scorpio, and Sagittarius, the north Pole *P* comes more and more into the light; the days increase as the nights decrease in length, at all places north of the Equator *Æ*; which is plain by viewing the Earth at *b* on the 5th of *May*, when it is in the 15th degree of Scorpio †, and

* Here we must suppose the Sun to be no bigger than an ordinary point (as .) because he only covers a Circle half a degree in diameter in the Heavens; whereas in the figure he hides a whole sign at once from the Earth.

† Here we must suppose the Earth to be a much smaller point than that in the preceding note marked for the Sun.

PLATE V. Fig. II. the Sun, as seen from the Earth, appears in the 15th degree of Taurus. For then, the Tropic of Cancer *T* is in the light from a little after five in the morning till almost seven in the evening; the parallel of *London* from half a hour past four till half a hour past seven; the polar Circle *U* from three till nine; and a large track round the north Pole *P* has day all the 24 hours, for many rotations of the Earth on its Axis.

When the Earth comes to *c*, at the beginning of Capricorn, and the Sun, as seen from the Earth, appears at the beginning of Cancer, on the 21st of *June*, as in this Figure, it is in the position *a* in Fig. I.; and its north Pole inclines toward the Sun, so as to bring all the north frigid Zone into the light, and the northern parallels of Latitude more into the light than the dark from the Equator to the polar Circle; and the more so as they are farther from the Equator. The Tropic of Cancer is in the light from five in the morning till seven at night; the parallel of *London* from a quarter before four till a quarter after eight; and the polar Circle just touches the dark, so that the Summer Solstice. Sun has only the lower half of his Disc hid from the inhabitants on that Circle for a few minutes about midnight, supposing no inequalities in the Horizon, and no refractions.

A bare view of the Figure is enough to shew, that as the Earth advances from Capricorn toward Aries, and the Sun appears to move from Cancer toward Libra, the north Pole advances toward the dark, which causes the days to decrease, and the nights to increase in length, till the Earth comes Autumnal Equinox. to the beginning of Aries, and then they are equal as before; for the boundary of light and darkness cuts the Equator and all its parallels equally, or in halves. The north Pole then goes into the dark, and continues in it until the Earth goes half way round its Orbit; or, from the 23d of *September* till the 20th of *March*. In the middle between theſe times, *viz.* on the 22d of *December*, the north Pole is as far as it can be in the dark, which is 23½ degrees, equal to the inclination of the Earth's Axis from a perpendicular to its Orbit: and then the northern parallels are as much in the dark as they were in the light on the 21ſt of *June*; the winter nights being as long as the ſummer days, and the winter days as ſhort as the ſummer nights. It is needleſs to enlarge farther on this ſubject, as we ſhall have occaſion to mention the ſeaſons again in deſcribing the *Orrery*, § 397. Only this muſt be noted, that whatever has been ſaid of the northern Hemiſphere, the contrary muſt be underſtood of the ſouthern; for on different ſides of the Equator the ſeaſons are contrary, becauſe, when the northern Hemiſphere inclines toward the Sun, the ſouthern declines from him. Winter Solſtice.

204. As Saturn goes round the Sun, his obliquely poſited ring, like our Earth's Axis, keeps parallel to itſelf, and is therefore turned edgewiſe to the Sun twice in a Saturnian year, which is almoſt as long as 30 of our years, § 81. But the ring, though conſiderably broad, is too thin to be ſeen by us when it is turned edgewiſe to the Sun, at which time it is alſo edgewiſe to the Earth; and therefore it diſappears once in every fifteen years to us. As the Sun ſhines half a year together on the north Pole of our Earth, then diſappears to it, and ſhines as long on the ſouth Pole; ſo, during one half of Saturn's year, the Sun ſhines on the north ſide of his ring, then diſappears to it, and ſhines as long on its ſouth ſide. When the Earth's Axis inclines neither to nor from the Sun, but ſidewiſe to him, he inſtantly ceaſes to ſhine on one Pole, and begins to enlighten the other; and when Saturn's ring inclines neither to nor from the Sun, but ſidewiſe The Phenomena of Saturn's Ring.

to

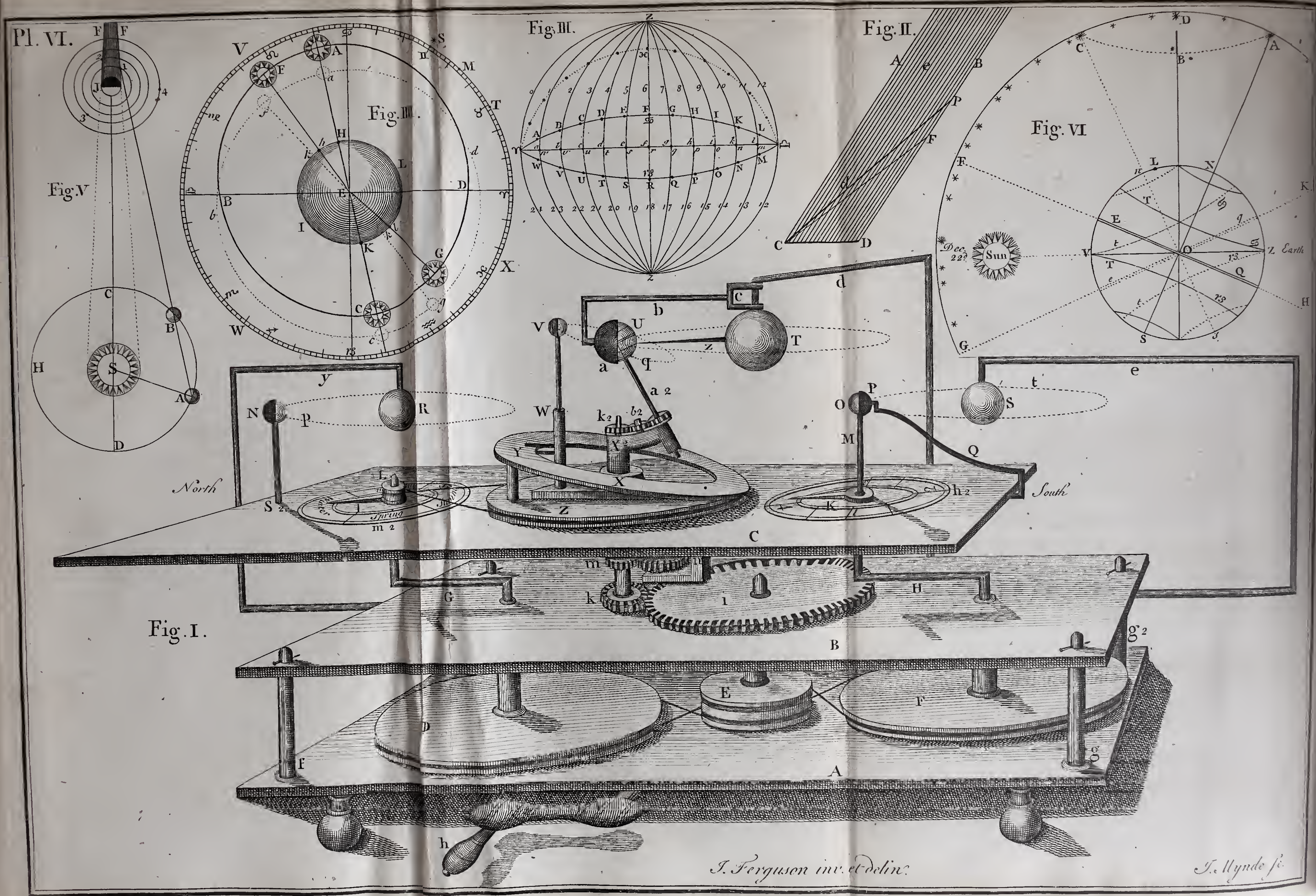
PLATE V. to him, he ceaſes to ſhine on the one ſide of it, and begins to ſhine upon the other.

Fig. III. Let *S* be the *Sun*, *ABCDEFGH* Saturn's Orbit, and *IKLMNO* the Earth's Orbit. Both Saturn and the Earth move according to the order of the letters, and when Saturn is at *A* his ring is turned edgewiſe to the Sun *S*, and he is then ſeen from the Earth as if he had loſt his ring, let the Earth be in any part of its Orbit whatever, except between *N* and *O*; for while it deſcribes that ſpace, Saturn is apparently ſo near the Sun as to be hid in his beams. As Saturn goes from *A* to *C*, his ring appears more and more open to the Earth: at *C* the ring appears moſt open of all; and ſeems to grow narrower and narrower as Saturn goes from *C* to *E*; and when he comes to *E*, the ring is again turned edgewiſe both to the Sun and Earth; and as neither of its ſides are illuminated, it is inviſible to us, becauſe its edge is too thin to be perceptible; and Saturn appears again as if he had loſt his ring. But as he goes from *E* to *G*, his ring opens more and more to our view on the under ſide; and ſeems juſt as open at *G* as it was at *C*; and may be ſeen in the night-time from the Earth in any part of its Orbit, except about *M*, when the Sun hides the Planet from our view. As Saturn goes from *G* to *A*, his ring turns more and more edgewiſe to us, and therefore it ſeems to grow narrower and narrower; and at *A* it diſappears as before. Hence, while Saturn goes from *A* to *E*, the Sun ſhines on the upper ſide of his ring, and the under ſide is dark; and while he goes from *E* to *A*, the Sun ſhines on the under ſide of his ring, and the upper ſide is dark.

It may perhaps be imagined that this Article might have been placed more properly after § 81, than here; but when the candid reader conſiders

Fig. I. and II. that all the various Phenomena of Saturn's Ring depend upon a cauſe ſimilar to that of our Earth's

 ſeaſons,


Pl. VI.
Fig. V
Fig. IIII.
Fig. III.
Fig. II.
Fig. VI
Sun
Dec. 22d
Earth
North
South
Spring
Fig. I.
J. Ferguson inv. et delin.
J. Mynde sc.

feasons, he will readily allow that they are beft explained together; and that the two Figures ferve to illuftrate each other. PLATE VI.

205. The Earth's Orbit being elliptical, and the Sun keeping conftantly in its lower Focus, which is 1,377,000 miles from the middle point of the longer Axis, the Earth comes twice fo much, or 2,754,000 miles nearer the Sun at one time of the year than at another: for the Sun appearing under a larger Angle in our winter than fummer, proves that the Earth is nearer the Sun in winter (*fee the Note on Article* 185). But here this natural queftion will arife, why have we not the hotteft weather when the Earth is neareft the Sun? In anfwer it muft be obferved, that the excentricity of the Earth's Orbit, or 1,377,000 miles, bears no greater proportion to the Earth's mean diftance from the Sun, than 17 does to 1000; and therefore this fmall difference of diftance cannot occafion any great difference of heat or cold. But the principal caufe of this difference is, that in winter the Sun's rays fall fo obliquely upon us, that any given number of them is fpread over a much greater portion of the Earth's furface where we live, and therefore each point muft then have fewer rays than in fummer. Moreover, there comes a greater degree of cold in the long winter nights, than there can return of heat in fo fhort days; and on both thefe accounts the cold muft increafe. But in fummer the Sun's rays fall more perpendicularly upon us, and therefore come with greater force, and in greater numbers on the fame place; and by their long continuance, a much greater degree of heat is imparted by day than can fly off by night.

The Earth nearer the Sun in winter than in fummer.

Why the weather is coldeft when the Earth is neareft the Sun.

206. That a greater number of rays fall on the fame place, when they come perpendicularly, than when they come obliquely on it, will appear by the Figure. For, let *AB* be a certain number of the Sun's rays falling on *CD* (which let us fuppofe to be *London*) on the 21ft of *June*: but, on the

Fig. II.

the 22d of *December*, the line *CD*, or *London*, has the oblique position *Cd* to the same rays; and therefore scarce a third part of them falls upon it, or only those between *A* and *e*; all the rest *eB* being expended on the space *dP*, which is more than double the length of *CD* or *Cd*. Besides, those parts which are once heated, retain the heat for some time; which, with the additional heat daily imparted, makes it continue to increase, though the Sun declines toward the South: and this is the reason why *July* is hotter than *June*, although the Sun has withdrawn from the Summer Tropic; as we find it is generally hotter at three in the afternoon, when the Sun has gone toward the west, than at noon when he is on the Meridian. Likewise, those places which are well cooled require time to be heated again; for the Sun's rays do not heat even the surface of any body till they have been some time upon it. And therefore we find *January* for the most part colder than *December*, although the Sun has withdrawn from the winter Tropic, and begins to dart his beams more perpendicularly upon us, when we have the position *CF*. An iron bar is not heated immediately upon being put into the fire, nor grows cold till some time after it has been taken out.

CHAP. XI.

The Method of finding the Longitude by the Eclipses of Jupiter's Satellites: The amazing Velocity of Light demonstrated by these Eclipses.

First Meridian, and Longitude of places, what.

207. GEographers arbitrarily choose to call the Meridian of some remarkable place *the first Meridian*. There they begin their reckoning; and just so many degrees and minutes as any other place is to the eastward or westward of that Meridian, so much east or west Longitude they say it has. A degree is the 360th part of a Circle, be it great

great or ſmall; and a minute the 60th part of a degree. The *Engliſh* Geographers reckon the Longitude from the Meridian of the Royal Obſervatory at *Greenwich*, and the *French* from the Meridian of *Paris*. PLATE V.

208. If we imagine twelve great Circles, one of which is the Meridian of any given place, to interſect each other in the two Poles of the Earth, and to cut the Equator *Æ* at every 15th degree, they will be divided by the poles into 24 Semi-circles, which divide the Equator into 24 equal parts; and as the Earth turns on its Axis, the planes of theſe Semi-circles come ſucceſſively one after another every hour to the Sun. As in a hour of time there is a revolution of fifteen degrees of the Equator, in a minute of time there will be a revoluion of 15 minutes of the Equator, and in a ſecond of time a revolution of 15 ſeconds. There are two tables annexed to this Chapter, for reducing mean ſolar time into degrees and minutes of the terreſtrial Equator; and alſo for converting degrees and parts of the Equator into mean ſolar time. Fig. II. Hour Circles. A hour of time equal to 15 degrees of motion.

209. Becauſe the Sun enlightens only one half of the Earth at once, as it turns round its Axis, he riſes to ſome places at the ſame moment of abſolute Time that he ſets at to others; and when it is mid-day to ſome places, it is mid-night to others. The XII on the middle of the Earth's enlightened ſide, next the Sun, ſtands for mid-day; and the oppoſite XII, on the middle of the dark ſide, for mid-night. If we ſuppoſe this Circle of hours to be fixed in the plane of the Equinoctial, and the Earth to turn round within it, any particular Meridian will come to the different hours ſo, as to ſhew the true time of the day or night at all places on that Meridian. Therefore,

210. To every place 15 degrees eaſtward from any given Meridian, it is noon a hour ſooner than on that Meridian; becauſe their Meridian comes to

to the Sun a hour fooner: and to all places 15 degrees weftward, it is noon a hour later, § 208, becaufe their Meridian comes a hour later to the Sun; and fo on: every 15 degrees of motion cauf-ing a hour's difference of time. Therefore they who have noon a hour later than we, have their Meridian, that is, their Longitude, 15 degrees weftward from us; and they who have noon a hour fooner than we, have their Meridian 15 degrees eaftward from ours: and fo for every hour's difference of time 15 degrees difference of Longitude. Confequently, if the beginning or ending of a Lunar Eclipfe be obferved, fuppofe at *London*, to be exactly at mid-night, and in fome other place at 11 at night, that place is 15 degrees weftward from the Meridian of *London*: if the fame Eclipfe be obferved at one in the morning at another place, that place is 15 degrees eaftward from the faid Meridian.

And confequently to 15 degrees of Longitude.

Lunar eclipfes ufeful in finding the Longitude.

211. But as it is not eafy to determine the exact moment either of the beginning or ending of a Lunar Eclipfe, becaufe the Earth's fhadow through which the Moon paffes is faint and ill-defined about the edges, we have recourfe to the Eclipfes of Jupiter's Satellites, which difappear much more quickly as they enter into Jupiter's fhadow, and emerge more fuddenly out of it. The firft or neareft Satellite to Jupiter is the moft advantageous for this purpofe, becaufe its motion is quicker than the motion of any of the reft, and therefore its immerfions and emerfions are more frequent and more fudden than thofe of others are.

Eclipfes of Jupiter's Satellites much better for that purpofe.

212. The *Englifh* Aftronomers have calculated Tables for fhewing the times of the Eclipfes of Jupiter's Satellites to great precifion, for the Meridian at *Greenwich*. Now, let an obferver, who has thefe Tables, with a good Telefcope and a well-regulated Clock, at any other place of the Earth, obferve the beginning or ending of an Eclipfe of one

one of Jupiter's Satellites, and not the precise moment of time that he saw the Satellite either immerge into, or emerge out of the shadow, and compare that time with the time shewn by the Tables for *Greenwich*; then 15 degrees difference of Longitude being allowed for every hour's difference of time, will give the Longitude of that place from *Greenwich*, as above, § 210; and if there be any odd minutes of time, for every minute a quarter of a degree, east or west, must be allowed, as the time of observation is later or earlier than the time shewn by the Tables. Such Eclipses are very convenient for this purpose at land, because they happen almost every day; but are of no use at sea, because the rolling of the ship hinders all nice telescopical observations.

PLATE V. How to solve this important problem.

213. To explain this by a Figure, let *J* be Jupiter, *K*, *L*, *M*, *N*, his four Satellites in their respective Orbits 1, 2, 3, 4; and let the Earth be at *f*, suppose in *November*, although that Month is no otherwise material than to find the Earth readily in this scheme, where it is shewn in eight different parts of its Orbit. Let *Q* be a place on the Meridian of *Greenwich*, and *R* a place on some other Meridian eastward from *Greenwich*. Let a person at *R* observe the instantaneous vanishing of the first Satellite *K* into Jupiter's shadow, suppose at three in the morning; but by the Tables he finds the immersion of that Satellite to be at mid-night at *Greenwich*: he can then immediately determine, that, as there are three hours difference of time between *Q* and *R*, and that *R* is three hours forwarder in reckoning than *Q*, it must be 45 degrees of east Longitude from the Meridian of *Q*. Were this method as practicable at sea as at land, any sailor might almost as easily, and with almost equal certainty, find the Longitude as the Latitude.

Fig. II. Illustrated by an example.

214. While the Earth is going from *C* to *F* in its Orbit, only the immersions of Jupiter's Satellites

Fig. II.

We feldom fee the beginning and end of the fame Eclipfe of any of Jupiter's Moons.

lites into his fhadow are generally feen; and their emerfions out of it while the Earth goes from *G* to *B*. Indeed, both thefe appearances may be feen of the fecond, third, and fourth Satellite when eclipfed, while the Earth is between *D* and *E*, or between *G* and *A*; but never of the firft Satellite, on account of the fmallnefs of its Orbit and the bulk of Jupiter; except only when Jupiter is directly oppofite to the Sun, that is, when the Earth is at *g*: and even then, ftrictly fpeaking, we cannot fee either the immerfions or emerfions of any of his Satellites, becaufe his body being directly between us and his conical fhadow, his Satellites are hid by his body a few moments before they touch his fhadow; and are quite emerged from thence before we can fee them, as it were, juft dropping from behind him. And when the Earth is at *c*, the Sun, being between it and Jupiter, hides both him and his moons from us.

In this Diagram, the Orbits of Jupiter's Moons are drawn in true proportion to his diameter; but in proportion to the Earth's Orbit, they are drawn 81 times too large.

Jupiter's conjunctions with the Sun, or oppofitions to him, are every year in different parts of the Heavens.

215. In whatever month of the year Jupiter is in conjunction with the Sun, or in oppofition to him, in the next year it will be a month later at leaft. For while the Earth goes once round the Sun, Jupiter defcribes a twelfth part of his Orbit. And therefore, when the Earth has finifhed its annual period from being in a line with the Sun and Jupiter, it muft go as much forwarder as Jupiter has moved in that time, to overtake him again: juft like the minute-hand of a watch, which muft, from any conjunction with the hour-hand, go once round the dial-plate and fomewhat above a twelfth part more, to overtake the hour-hand again.

216. It is found by obfervation, that when the Earth is between the Sun and Jupiter, as at *g*, his Satellites

Satellites are eclipſed about 8 minutes ſooner than they ſhould be according to the Tables; and when the Earth is at *B* or *C*, theſe Eclipſes happen about 8 minutes later than the Tables predict them. Hence it is undeniably certain, that the motion of Light is not inſtantaneous, ſince it takes about 16½ minutes of time to go through a ſpace equal to the diameter of the Earth's Orbit, which is 190 millions of miles in length; and conſequently the particles of Light fly about 193 thouſand 939 miles every ſecond of time, which is above a million of times ſwifter than the motion of a cannon-ball. And as light is 16½ minutes in travelling acroſs the Earth's Orbit, it muſt be 8¼ minutes in coming from the Sun to us; therefore, if the Sun were annihilated, we ſhould ſee him for 8¼ minutes after; and if he were again created, he would be 8¼ minutes old before we could ſee him.

PLATE V.

The ſurpriſing velocity of Light.

217. To explain the progreſſive motion of Light, let *A* and *B* be the Earth, in two different parts of its Orbit, whoſe diſtance from each other is 95 millions of miles, equal to the Earth's diſtance from the Sun *S*. It is plain, that if the motion of Light were inſtantaneous, the Satellite 1 would appear to enter into Jupiter's ſhadow *FF* at the ſame moment of time to a ſpectator in *A* as to another in *B*. But by many years obſervations it has been found, that the immerſion of the Satellite into the ſhadow is ſeen 8¼ minutes ſooner when the Earth is at *B*, than when it is at *A*. And ſo, as Mr. ROEMER firſt diſcovered, the motion of Light is thereby proved to be progreſſive, and not inſtantaneous, as was formerly believed. It is eaſy to compute in what time the Earth moves from *A* to *B*; for the Chord of 60 degrees of any Circle is equal to the Semi-diameter of that Circle; and as the Earth goes through all the 360 degrees of its Orbit in a year, it goes through 60 of thoſe degrees in about 61 days. Therefore, if

Fig. V.

Illuſtrated by a Figure.

if on any given day, ſuppoſe the firſt of *June*, the Earth is at *A*, on the firſt of *Auguſt* it will be at *B:* the chord, or ſtraight line *AB*, being equal to *DS*, the Radius of the Earth's Orbit, the ſame with *AS*, its diſtance from the Sun.

218. As the Earth moves from *D* to *C*, through the ſide *AB* of its Orbit, it is conſtantly meeting the light of Jupiter's Satellites ſooner, which occaſions an apparent acceleration of their Eclipſes: and as it moves through the other half *H* of its Orbit from *C* to *D*, it is receding from their light, which occaſions an apparent retardation of their Eclipſes, becauſe their light is then longer before it overtakes the Earth.

219. That theſe accelerations of the immerſions of Jupiter's Satellites into his ſhadow, as the Earth approaches toward Jupiter, and the retardations of their emerſions out of his ſhadow, as the Earth is going from him, are not occaſioned by any inequality ariſing from the motions of the Satellites in excentric Orbits, is plain, becauſe it affects them all alike, in whatever parts of their Orbits they are eclipſed. Beſides, they go often round their Orbits every year, and their motions are no way commenſurate to the Earth's. Therefore, a Phenomenon, not to be accounted for from the real motions of the Satellites, but ſo eaſily deducible from the Earth's motion, and ſo anſwerable thereto, muſt be allowed to reſult from it. This affords one very good proof of the Earth's annual motion.

220. TABLES for converting mean ſolar TIME into Degrees and Parts of the terreſtrial EQUATOR; and alſo for converting Degrees and Parts of the EQUATOR into mean ſolar TIME.

TABLE I. For converting Time into Degrees and Parts of the Equator.								TABLE II. For converting Degrees and Parts of the Equator into Time.								
Hours	Degrees	*Min. | Sec. | Thirds	Deg. | Min. | Sec.	Min. | Sec. | Thirds	*Min. | Sec. | Thirds	Deg. | Min. | Sec.	Min. | Sec. | Thirds	*Deg. | Min. | Sec.	Hours | Min. | Sec.	Min. | Sec. | Thirds	*Deg. | Min. | Sec.	Hours | Min. | Sec.	Min. | Sec. | Thirds	Degrees	Hours	Minutes
1	15	1	0	15	31	7	45	1	0	4	31	2	4	70	4	40
2	30	2	0	30	32	8	0	2	0	8	32	2	8	80	5	20
3	45	3	0	45	33	8	15	3	0	12	33	2	12	90	6	0
4	60	4	1	0	34	8	30	4	0	16	34	2	16	100	6	40
5	75	5	1	15	35	8	45	5	0	20	35	2	20	110	7	20
6	90	6	1	30	36	9	0	6	0	24	36	2	24	120	8	0
7	105	7	1	45	37	9	15	7	0	28	37	2	28	130	8	40
8	120	8	2	0	38	9	30	8	0	32	38	2	32	140	9	20
9	135	9	2	15	39	9	45	9	0	36	39	2	36	150	10	0
10	150	10	2	30	40	10	0	10	0	40	40	2	40	160	10	40
11	165	11	2	45	41	10	15	11	0	44	41	2	44	170	11	20
12	180	12	3	0	42	10	30	12	0	48	42	2	48	180	12	0
13	195	13	3	15	43	10	45	13	0	52	43	2	52	190	12	40
14	210	14	3	30	44	11	0	14	0	56	44	2	56	200	13	20
15	225	15	3	45	45	11	15	15	1	0	45	3	0	210	14	0
16	240	16	4	0	46	11	30	16	1	4	46	3	4	220	14	40
17	255	17	4	15	47	11	45	17	1	8	47	3	8	230	15	20
18	270	18	4	30	48	12	0	18	1	12	48	3	12	240	16	0
19	285	19	4	45	49	12	15	19	1	16	49	3	16	250	16	40
20	300	20	5	0	50	12	30	20	1	20	50	3	20	260	17	20
21	315	21	5	15	51	12	45	21	1	24	51	3	24	270	18	0
22	330	22	5	30	52	13	0	22	1	28	52	3	28	280	18	40
23	345	23	5	45	53	13	15	23	1	32	53	3	32	290	19	20
24	360	24	6	0	54	13	30	24	1	36	54	3	36	300	20	0
25	375	25	6	15	55	13	45	25	1	40	55	3	40	310	20	40
26	390	26	6	30	56	14	0	26	1	44	56	3	44	320	21	20
27	405	27	6	45	57	14	15	27	1	48	57	3	48	330	22	0
28	420	28	7	0	58	14	30	28	1	52	58	3	52	340	22	40
29	435	29	7	15	59	14	45	29	1	56	59	3	56	350	23	20
30	450	30	7	30	60	15	0	30	2	0	60	4	0	360	24	0

Theſe are the Tables mentioned in the 208th article, and are ſo eaſy that they ſcarce require any farther explanation than to inform the reader, that if, in Table I. he reckons the columns marked with Aſteriſks to be minutes of time, the other columns give the equatoreal parts or motion in degrees and minutes; if he reckons the Aſteriſk columns to be ſeconds, the others give the motion in minutes and ſeconds of the Equator; if thirds, in ſeconds and thirds: And if in Table II. he reckons the Aſteriſk columns to be degrees of motion, the others give the time anſwering thereto in hours and minutes; if minutes of motion, the time is minutes and ſeconds; if ſeconds of motion, the correſponding time is given in ſeconds and thirds. An example in each caſe will make the whole very plain.

Example I.

In 10 hours 15 minutes 24 ſeconds 20 thirds, *Qu.* How much of the Equator revolves through the Meridian?

		Deg.	M.	S.
Hours	10	150	0	0
Min.	15	3	45	0
Sec.	24		6	0
Thirds	20			5
Anſwer		153	51	5

Example II.

In what time will 153 degrees 51 minutes 5 ſeconds of the Equator revolve through the Meridian?

		H.	M.	S.	T
Deg.	150	10	0	0	0
Deg.	3		12	0	0
Min.	51		3	24	0
Sec.	5				20
Anſwer		10	15	24	20

C H A P. XII.

Of Solar and Sydereal Time.

Sydereal days ſhorter than ſolar days, and why.

221. THE Stars appear to go round the Earth in 23 hours 56 minutes 4 ſeconds, and the Sun in 24 hours: ſo that the Stars gain three minutes 56 ſeconds upon the Sun every day, which amounts

amounts to one diurnal revolution in a year; and therefore, in 365 days, as measured by the returns of the Sun to the Meridian, there are 366 days, as measured by the Stars returning to it; the former are called *Solar Days*, and the latter *Sydereal*. PLATE III.

The diameter of the Earth's Orbit is but a physical point in proportion to the distance of the Stars; for which reason, and the Earth's uniform motion on its Axis, any given Meridian will revolve from any Star to the same Star again in every absolute turn of the Earth on its Axis, without the least perceptible difference of time shewn by a Clock which goes exactly true.

If the Earth had only a diurnal motion, without an annual, any given Meridian would revolve from the Sun to the Sun again in the same quantity of time as from any Star to the same Star again; because the Sun would never change his place with respect to the Stars. But, as the Earth advances almost a degree eastward in its Orbit in the time that it turns eastward round its Axis, whatever Star passes over the Meridian on any day with the Sun, will pass over the same Meridian on the next day when the Sun is almost a degree short of it; that is, 3 minutes 56 seconds sooner. If the year contained only 360 days, as the Ecliptic does 360 degrees, the Sun's apparent place, so far as his motion is equable, would change a degree every day; and then the sydereal days would be just 4 minutes shorter than the solar.

Let *ABCDEFGHIKLM* be the Earth's Orbit, Fig. II. in which it goes round the Sun every year according to the order of the letters, that is, from west to east; and turns round its Axis the same way from the Sun to the Sun again in every 24 hours. Let *S* be the Sun, and *R* a fixed Star at such an immense distance, that the diameter of the Earth's Orbit bears no sensible proportion to that distance. Let *Nm* be any particular Meridian of the Earth, and *N* a given point or place upon that Meridian.

When

When the Earth is at *A*, the Sun *S* hides the Star *R*, which would be always hid if the Earth never removed from *A*; and consequently, as the Earth turns round its Axis, the point *N* would always come round to the Sun and Star at the same time. But when the Earth has advanced, suppose a twelfth part of its Orbit from *A* to *B*, its motion round its Axis will bring the point *N* a twelfth part of a natural day, or two hours, sooner to the Star than to the Sun; for the Angle *NBn* is equal to the Angle *ASB*: and therefore any Star, which comes to the Meridian at noon with the Sun when the Earth is at *A*, will come to the Meridian at 10 in the forenoon when the Earth is at *B*. When the Earth comes to *C*, the point *N* will have the Star on its Meridian at 8 in the morning, or four hours sooner than it comes round to the Sun; for it must revolve from *N* to *n* before it has the Sun in its Meridian. When the Earth comes to *D*, the point *N* will have the Star on its Meridian at 6 in the morning, but that point must revolve six hours more from *N* to *n*, before it has mid-day by the Sun: for now the Angle *ASD* is a right Angle, and so is *NDn*; that is, the Earth has advanced 90 degrees in its Orbit, and must turn 90 degrees on its Axis to carry the point *N* from the Star to the Sun: for the Star always comes to the Meridian when *Nm* is parallel to *RSA*; because *DS* is but a point in respect of *RS*. When the Earth is at *E*, the Star comes to the Meridian at 4 in the morning; at *F*, at 2 in the morning; and at *G*, the Earth having gone half round its Orbit, *N* points to the Star *R* at midnight, it being then directly opposite to the Sun. And therefore, by the Earth's diurnal motion, the Star comes to the Meridian 12 hours before the Sun. When the Earth is at *H*, the Star comes to the Meridian at 10 in the evening; at *I* it comes to the Meridian at 8, that is, 16 hours before the Sun; at *K* 18 hours before him; at *L* 20 hours; at *M* 22; and at *A* equally with the Sun again.

A TABLE, shewing how much of the Celestial Equator passes over the Meridian in any Part of a mean SOLAR DAY; and how much the FIXED STARS gain upon the mean SOLAR TIME every Day, for a Month.

Time	Motion.			Time	Motion.			Time	Motion.			Acceleration of the Fixed Stars.			
Hours	Degrees	Minutes	Seconds	*Min. / Sec. / Th.	Deg. / Min. / Sec.	Min. / Sec. / Th.	Sec. / Th. / ''''	*Min. / Sec. / Th.	Deg. / Min. / Sec.	Min. / Sec. / Th.	Sec. / Th. / ''''	D.	H.	M.	S.
1	15	2	28	1	0	15	2	31	7	46	16	1	0	3	56
2	30	4	56	2	0	30	5	32	8	1	19	2	0	7	52
3	45	7	24	3	0	45	7	33	8	16	21	3	0	11	48
4	60	9	51	4	1	0	10	34	8	31	24	4	0	15	44
5	75	12	19	5	1	15	12	35	8	46	26	5	0	19	39
6	90	14	47	6	1	30	15	36	9	1	29	6	0	23	35
7	105	17	15	7	1	45	17	37	9	16	31	7	0	27	31
8	120	19	43	8	2	0	20	38	9	31	34	8	0	31	27
9	135	22	11	9	2	15	22	39	9	46	36	9	0	35	23
10	150	24	38	10	2	30	25	40	10	1	39	10	0	39	19
11	165	27	6	11	2	45	27	41	10	16	41	11	0	43	15
12	180	29	34	12	3	0	30	42	10	31	43	12	0	47	11
13	195	32	2	13	3	15	32	43	10	46	46	13	0	51	7
14	210	34	30	14	3	30	34	44	11	1	48	14	0	55	3
15	225	36	58	15	3	45	37	45	11	16	51	15	0	58	59
16	240	39	26	16	4	0	39	46	11	31	53	16	1	2	55
17	255	41	53	17	4	15	41	47	11	46	56	17	1	6	50
18	270	44	21	18	4	30	44	48	12	1	58	18	1	10	46
19	285	46	49	19	4	45	47	49	12	17	1	19	1	14	[illegible]
20	300	49	17	20	5	0	49	50	12	32	3	20	1	18	38
21	315	51	45	21	5	15	52	51	12	47	6	21	1	22	34
22	330	54	13	22	5	30	54	52	13	2	8	22	1	26	30
23	345	56	40	23	5	45	57	53	13	17	11	23	1	30	26
24	360	59	8	24	6	0	59	54	13	32	13	24	1	34	22
25	376	1	36	25	6	16	2	55	13	47	16	25	1	38	18
26	391	4	4	26	6	31	4	56	14	2	18	26	1	42	14
27	406	6	32	27	6	46	7	57	14	17	20	27	1	46	10
28	421	9	59	28	7	1	9	58	14	32	23	28	1	50	5
29	436	11	27	29	7	16	11	59	14	47	25	29	1	54	1
30	451	13	55	30	7	31	14	60	15	2	28	30	1	57	57

PLATE III.

An abſolute turn of the Earth on its Axis never finiſhes a ſolar day.

222. Thus it is plain, that an abſolute turn of the Earth on its Axis (which is always completed when any particular Meridian comes to be parallel to its ſituation at any time of the day before) never brings the ſame Meridian round from the Sun to the Sun again; but that the Earth requires as much more than one turn on its Axis to finiſh a natural day, as it has gone forward in that time; which, at a mean ſtate, is a 365th part of a Circle. Hence, in 365 days, the Earth turns 366 times round its Axis; and therefore, as a turn of the Earth on its Axis completes a ſydereal day, there muſt be one ſydereal day more in a year than the number of ſolar days, be the number what it will on the Earth, or any other Planet, one turn being loſt with reſpect to the number of ſolar days in a year, by the Planet's going round the Sun; juſt as it would be loſt to a traveller, who, in going round the Earth, would loſe one day by following the apparent diurnal motion of the Sun; and conſequently would reckon one day leſs at his return (let him take what time he would to go round the Earth) than thoſe who remained all the while at the place from which he ſet out. So, if there were two Earths revolving equally on their Axis, and if one remained at *A* until the other had gone round the Sun from *A* to *A* again, *that* Earth which kept its place at *A* would have its ſolar and ſydereal days always of the ſame length; and ſo would have one ſolar day more than the other at its return. Hence, if the Earth turned but once round its Axis in a year, and if *that* turn was made the ſame way as the Earth goes round the Sun, there would be continual day on one ſide of the Earth, and continual night on the other.

Fig. II.

223. The firſt part of the preceding Table ſhews how much of the celeſtial Equator paſſes over the Meridian in any given part of a mean ſolar day, and is to be underſtood the ſame way as the Table in the 220th article. The latter part, intituled, *Accele-*

Accelerations of the fixed Stars, affords us an eaſy method of knowing whether or no our clocks and watches go true: for if, through a ſmall hole in a window-ſhutter, or in a thin plate of metal fixed to a window, we obſerve at what time any Star diſappears behind a chimney, or corner of a houſe, at a little diſtance; and if the ſame Star diſappears the next night 3 minutes 56 ſeconds ſooner by the clock or watch; and on the ſecond night, 7 minutes 52 ſeconds ſooner; the third night 11 minutes 48 ſeconds ſooner; and ſo on, every night, as in the Table, which ſhews this difference for 30 natural days, it is an infallible ſign that the machine goes true; otherwiſe it does not go true, and muſt be regulated accordingly; and as the diſappearing of a Star is inſtantaneous, we may depend on this information to half a ſecond.

To know by the Stars whether a Clock goes true or not.

CHAP. XIII.

Of the Equation of Time.

224. THE Earth's motion on its Axis being perfectly uniform, and equal at all times of the year, the ſydereal days are always preciſely of an equal length; and ſo would the ſolar or natural days be, if the Earth's Orbit were a perfect Circle, and its Axis perpendicular to its Orbit. But the Earth's diurnal motion on an inclined Axis, and its annual motion in an elliptic Orbit, cauſe the Sun's apparent motion in the Heavens to be unequal: for ſometimes he revolves from the Meridian to the Meridian again in ſomewhat leſs than 24 hours, ſhewn by a well-regulated clock; and at other times in ſomewhat more: ſo that the time ſhewn by an equal-going clock and a true Sun-dial is never the ſame but on the 14th of *April*, the 15th of *June*, the 31ſt of *Auguſt*, and the 23d of *December*. The clock, if it goes equably and true all the year round, will be before the Sun

The Sun and Clocks equal only on four days of the year.

 from

from the 23d of *December* till the 14th of *April*; from that time till the 16th of *June* the Sun will be before the clock; from the 15th of *June* till the 31ſt of *Auguſt* the clock will be again before the Sun; and from thence to the 23d of *December* the Sun will be faſter than the clock.

Uſe of the Equation Table.

225. The Tables of the Equation of natural days, at the end of the following Chapter, ſhew the time that ought to be pointed out by a well-regulated clock or watch, every day of the year, at the preciſe moment of ſolar noon; that is, when the Sun's center is on the Meridian, or when a true Sun-dial ſhews it to be preciſely Twelve. Thus, on the 5th of *January* in Leap-year, when the Sun is on the Meridian, it ought to be 5 minutes 52 ſeconds paſt twelve by the clock: and on the 15th of *May*, when the Sun is on the Meridian, the time by the clock ſhould be but 56 minutes 1 ſecond paſt eleven: in the former caſe, the clock is 5 minutes 52 ſeconds before the Sun; and in the latter caſe, the Sun is 3 minutes 59 ſeconds faſter than the clock. But without a Meridian Line, or a Tranſit Inſtrument fixed in the plane of the Meridian, we cannot ſet a Sun-dial true.

How to draw a Meridian Line.

226. The eaſieſt and moſt expeditious way of drawing a Meridian Line is this: Make four or five concentric Circles, about a quarter of an inch from one another, on a flat board about a foot in breadth; and let the outmoſt Circle be but little leſs than the board will contain. Fix a pin perpendicularly in the center, and of ſuch a length that its whole ſhadow may fall within the innermoſt Circle for at leaſt four hours in the middle of the day. The pin ought to be about an eighth part of an inch thick, and to have a round blunt point. The board being ſet exactly level in a place where the Sun ſhines, ſuppoſe from eight in the morning till four in the afternoon, about which hours the end of the ſhadow ſhould fall without

all the Circles; watch the times in the forenoon, when the extremity of the ſhortening ſhadow juſt touches the ſeveral Circles, and *there* make marks. Then, in the afternoon of the ſame day, watch the lengthening ſhadow, and where its end touches the ſeveral Circles in going over them, make marks alſo. Laſtly, with a pair of compaſſes, find exactly the middle point between the two marks on any Circle, and draw a ſtraight line from the center to that point; which Line will be covered at noon by the ſhadow of a ſmall upright wire, which ſhould be put in the place of the pin. The reaſon for drawing ſeveral Circles is, that in caſe one part of the day ſhould prove clear, and the other part ſomewhat cloudy, if you miſs the time when the point of the ſhadow ſhould touch one Circle, you may perhaps catch it in touching another. The beſt time for drawing a Meridian Line in this manner is about the ſummer ſolſtice; becauſe the Sun changes his declination ſloweſt and his altitude faſteſt in the longeſt days.

If the caſement of a window on which the Sun ſhines at noon be quite upright, you may draw a line along the edge of its ſhadow on the floor, when the ſhadow of the pin is exactly on the Meridian Line of the board: and as the motion of the ſhadow of the caſement will be much more ſenſible on the floor than that of the ſhadow of the pin on the board, you may know to a few ſeconds when it touches the Meridian Line on the floor; and ſo regulate your clock for the day of obſervation by that line and the Equation Tables above mentioned, § 225.

227. As the equation of time, or difference between the time ſhewn by a well-regulated Clock and a true Sun-dial, depends upon two cauſes, namely, the obliquity of the Ecliptic, and the unequal motion of the Earth in it, we ſhall firſt explain Equation of natural days explained.

explain the effects of these causes separately, and then the united effects resulting from their combination.

228. The Earth's motion on its Axis being perfectly equable, or always at the same rate, and the * plane of the Equator being perpendicular to its Axis, it is evident that in equal times equal portions of the Equator pass over the Meridian; and so would equal portions of the Ecliptic, if it were parallel to or coincident with the Equator. But, as the Ecliptic is oblique to the Equator, the equable motion of the Earth carries unequal portions of the Ecliptic over the Meridian in equal times, the difference being proportionate to the obliquity; and as some parts of the Ecliptic are much more oblique than others, those differences are unequal among themselves. Therefore if two Suns should start either from the beginning of Aries or Libra, and continue to move through equal arcs in equal times, one in the Equator, and the other in the Ecliptic, the equatoreal Sun would always return to the Meridian in 24 hours time, as measured by a well-regulated clock; but the Sun in the Ecliptic would return to the Meridian sometimes sooner, and sometimes later than the equatoreal Sun; and only at the same moments with him on four days of the year; namely, the 20th of *March*, when the Sun enters Aries; the 21st of *June*, when he enters Cancer; the 23d of *September*, when he enters Libra; and the 21st of *December*, when he enters Capricorn. But, as there is only one Sun, and his apparent motion is always in the Ecliptic, let us henceforth call him the real Sun, and the other, which is supposed to move in the Equator,

The first part of the Equation of Time.

* If the Earth were cut along the Equator, quite through the center, the flat surface of this section would be the plane of the Equator; as the paper contained within any Circle may be justly termed the plane of that Circle.

the fictitious: to which last, the motion of a well-regulated clock always answers. PLATE VI.

Let *Z* ♈ *z* ♎ be the Earth, *ZFRz* its Axis, *abcde*, &c. the Equator, *ABCDE*, &c. the northern half of the Ecliptic from ♈ to ♎ on the side of the Globe next the eye, and *MNOP*, &c. the southern half on the opposite side from ♎ to ♈. Let the points at *A*, *B*, *C*, *D*, *E*, *F*, &c. quite round from ♈ to ♈ again, bound equal portions of the Ecliptic, gone through in equal times by the real Sun; and those at *a*, *b*, *c*, *d*, *e*, *f*, &c. equal portions of the Equator described in equal times by the fictitious Sun; and let *Z* ♈ *z* be the Meridian. Fig. III.

As the real Sun moves obliquely in the Ecliptic, and the fictitious Sun directly in the Equator, with respect to the Meridian, a degree, or any number of degrees, between ♈ and *F* on the Ecliptic, must be nearer the Meridian *Z* ♈ *z*, than a degree, or any corresponding number of degrees on the Equator from ♈ to *f*; and the more so, as they are the more oblique: and therefore the true Sun comes sooner to the meridian every day while he is in the quadrant ♈ *F*, than the fictitious Sun does in the quadrant ♈ *f*; for which reason, the solar noon precedes noon by the clock, until the real Sun comes to *F*, and the fictitious to *f*, which two points, being equidistant from the Meridian, both Suns will come to it precisely at noon by the Clock.

While the real Sun describes the second quadrant of the Ecliptic *FGHIKL* from ♋ to ♎, he comes later to the Meridian every day than the fictitious Sun moving through the second quadrant of the Equator from *f* to ♎; for the points at *G*, *H*, *I*, *K*, and *L* being farther from the Meridian than their corresponding points at *g*, *h*, *i*, *k*, and *l*, they must be later in coming to it: and as both Suns come at the same moment to the point ♎, they come to the Meridian at the moment of noon by the Clock.

In

In departing from ♎ Libra, through the third quadrant, the real Sun going through *MNOPQ* toward ♑ at *R*, and the fictitious Sun through *mnopq* toward *r*, the former comes to the Meridian every day sooner than the latter, until the real Sun comes to ♑, and the fictitious to *r*, and then they both come to the Meridian at the same time.

Lastly, as the real Sun moves equably through *STUVW*, from ♑ toward ♈; and the fictitious Sun through *stuvw*, from *r* toward ♈, the former comes later every day to the Meridian than the latter, until they both arrive at the point ♈, and then they make it noon at the same time with the clock.

A Table of the Equation of Time depending on the Sun's place in the Ecliptic.

229. The annexed Table shews how much the Sun is faster or slower than the clock ought to be, so far as the difference depends upon the obliquity of the Ecliptic; of which the Signs of the first and third quadrants are at the head of the Table, and their Degrees at the left hand; and in these the Sun is faster than the Clock: the Signs of the second and fourth quadrants are at the foot of the Table, and their degrees at the right hand; in all which the Sun is slower than the Clock; so that entering the Table with the given Sign of the Sun's place at the head of the Table, and the degree of his place in that Sign at the left hand; or with the given Sign at the foot of the Table, and Degree at the right hand; in the angle of meeting is the number of minutes and seconds that the Sun is faster or slower than the clock; or in other words, the quantity of time in which the real Sun, when in that part of the Ecliptic, comes sooner or later to the meridian than the fictitious Sun in the Equator. Thus, when the Sun's place is ♉ Taurus 12 degrees, he is 9 minutes 47 seconds faster than the clock; and

and when his Place is ♋ Cancer 18 degrees, he is 6 minutes 2 seconds slower.

Degrees.	*Sun faster than the Clock in*						1st Q. 3d Q.
	♈ ♎		♉ ♏		♊ ♐		
	'	"	'	"	'	"	Deg.
0	0	0	8	23	8	45	30
1	0	20	8	34	8	35	29
2	0	40	8	43	8	24	28
3	1	0	8	53	8	13	27
4	1	19	9	1	8	0	26
5	1	39	9	9	7	48	25
6	1	59	9	17	7	34	24
7	2	18	9	24	7	20	23
8	2	37	9	30	7	6	22
9	2	56	9	35	6	50	21
10	3	15	9	40	6	35	20
11	3	34	9	44	6	18	19
12	3	52	9	47	6	2	18
13	4	11	9	50	5	44	17
14	4	28	9	52	5	27	16
15	4	46	9	53	5	8	15
16	5	3	9	54	4	50	14
17	5	20	9	54	4	31	13
18	5	37	9	53	4	11	12
19	5	53	9	51	3	52	11
20	6	09	9	49	3	32	10
21	6	25	9	46	3	11	9
22	6	40	9	42	2	51	8
23	6	54	9	37	2	30	7
24	7	9	9	32	2	9	6
25	7	22	9	26	1	48	5
26	7	36	9	19	1	26	4
27	7	48	9	12	1	5	3
28	8	0	9	4	0	43	2
29	8	12	8	55	0	22	1
30	8	23	8	45	0	0	0
2d Q. 4th Q.	♍ ♓		♌ ♒		♋ ♑		Deg.
	Sun slower than the Clock in						

This Table is formed by taking the difference between the Sun's longitude and its right ascension, and turning it into time.

230. This

PLATE III. Fig. III.

230. This part of the Equation of time may perhaps be ſomewhat difficult to underſtand by a Figure, becauſe both halves of the Ecliptic ſeem to be on the ſame ſide of the Globe: but it may be made very eaſy to any perſon who has a real Globe before him, by putting ſmall patches on every tenth or fifteenth degree both of the Equator and Ecliptic, beginning at Aries ♈; and then, turning the ball ſlowly round weſtward, he will ſee all the patches from Aries to Cancer come to the brazen Meridian ſooner than the correſponding patches on the Equator; all thoſe from Cancer to Libra will come later to the Meridian than their correſponding patches on the Equator; thoſe from Libra to Capricorn ſooner, and thoſe from Capricorn to Aries later; and the patches at the beginnings of Aries, Cancer, Libra, and Capricorn, being either on or even with thoſe on the Equator, ſhew that the two Suns either meet there, or are even with one another, and ſo come to the Meridian at the ſame moment.

A machine for ſhewing the ſydereal, the equal, and the ſolar Time.

231. Let us ſuppoſe that there are two little balls moving equably round a celeſtial Globe by clock-work, one always keeping in the Ecliptic, and gilt with gold, to repreſent the real Sun; and the other keeping in the Equator, and ſilvered, to repreſent the fictitious Sun: and that while theſe balls move once round the Globe according to the order of Signs, the Clock turns the Globe 366 times round its Axis weſtward. The Stars will make 366 diurnal revolutions from the brazen Meridian to it again; and the two balls repreſenting the real and fictitious Suns always going farther eaſtward from any given Star, will come later than it to the Meridian every following day: and each ball will make 365 revolutions to the Meridian; coming equally to it at the beginnings of Aries, Cancer, Libra, and Capricorn; but in every other point of the Ecliptic, the gilt ball will come either ſooner or later to the Meridian than

than the ſilvered ball, like the patches above-mentioned. This would be a pretty way enough of ſhewing the reaſon why any given Star, which on a certain day of the year, comes to the Meridian with the Sun, paſſes over it ſo much ſooner every following day, as on that day twelvemonth to come to the Meridian with the Sun again; and alſo to ſhew the reaſon why the real Sun comes to the Meridian ſometimes ſooner, and ſometimes later, than the time when it is noon by the clock; and, on four days of the year, at the ſame time; while the fictitious Sun always comes to the Meridian when it is twelve at noon by the clock. This would be no difficult taſk for an artiſt to perform; for the gold ball might be carried round the Ecliptic by a wire from its north Pole, and the ſilver ball round the Equator by a wire from its ſouth Pole, by means of a few wheels to each; which might be eaſily added to my improvement of the celeſtial Globe, deſcribed in N° 483 of the *Philoſophical Tranſactions*; and of which I ſhall give a deſcription in the latter part of this Book, from the third Figure of the third Plate. PLATE VI.

232. It is plain that if the Ecliptic were more obliquely poſited to the Equator, as the dotted Circle ♈ *x* ♎, the equal diviſions from ♈ to *x* would come ſtill ſooner to the Meridian *Z* o ♈ than thoſe marked *A*, *B*, *C*, *D*, and *E* do: for two diviſions containing 30 degrees, from ♈ to the ſecond dot, a little ſhort of the figure 1, come ſooner to the Meridian than one diviſion containing only 15 degrees from ♈ to *A* does, as the Ecliptic now ſtands; and thoſe of the ſecond quadrant from *x* to ♎ would be ſo much later. The third quadrant would be as the firſt, and the fourth as the ſecond. And it is likewiſe plain, that where the Ecliptic is moſt oblique, namely, about Aries and Libra, the difference would be greateſt; and leaſt about Cancer and Capricorn, where the obliquity is leaſt. Fig. IV.

234. Having

PLATE VI. The second part of the Equation of Time.

234. Having explained one cauſe of the difference of time ſhewn by a well-regulated Clock and a true Sun-dial, and conſidered the Sun, not the Earth, as moving in the Ecliptic, we now proceed to explain the other cauſe of this difference, namely, the inequality of the Sun's apparent motion, § 205, which is ſloweſt in ſummer, when the Sun is fartheſt from the Earth, and ſwifteſt in winter when he is neareſt to it. But the Earth's motion on its Axis is equable all the year round, and is performed from weſt to eaſt; which is the way that the Sun appears to change his place in the Ecliptic.

235. If the Sun's motion were equable in the Ecliptic, the whole difference between the equal time as ſhewn by the Clock, and the unequal time as ſhewn by the Sun, would ariſe from the obliquity of the Ecliptic. But the Sun's motion ſometimes exceeds a degree in 24 hours, though generally it is leſs; and when his motion is ſloweſt, any particular Meridian will revolve ſooner to him than when his motion is quickeſt; for it will overtake him in leſs time when he advances a leſs ſpace than when he moves through a larger.

236. Now, if there were two Suns moving in the plane of the Ecliptic, ſo as to go round it in a year; the one deſcribing an equal arc every 24 hours, and the other deſcribing ſometimes a leſs arc in 24 hours, and at other times a larger; gaining at one time of the year what it loſt at the oppoſite; it is evident that either of theſe Suns would come ſooner or later to the Meridian than the other, as it happened to be behind or before the other: and when they were both in conjunction, they would come to the meridian at the ſame moment.

237. As the real Sun moves unequably in the Ecliptic, let us ſuppoſe a fictitious Sun to move equably in a circle coincident with the plane of the Ecliptic. Let *ABCD* be the Ecliptic or Orbit in

Fig. IV.

in which the real Sun moves, and the dotted Circle *a b c d* the imaginary Orbit of the fictitious Sun; each going round in a year according to the order of letters, or from weſt to eaſt. Let *HIKL* be the Earth turning round its Axis the ſame way every 24 hours; and ſuppoſe both Suns to ſtart from *A* and *a*, in a right line with the plane of the Meridian *E H*, at the ſame moment: the real Sun at *A*, being then at his greateſt diſtance from the Earth, at which time his motion is ſloweſt; and the fictitious Sun at *a*, whoſe motion is always equable, becauſe his diſtance from the Earth is ſuppoſed to be always the ſame. In the time that the Meridian revolves from *H* to *H* again, according to the order of the letters *HIKL*, the real Sun has moved from *A* to *F*; and the fictitious with a quicker motion from *a* to *f*, through a larger arc; therefore, the Meridian *E H* will revolve ſooner from *H* to *h* under the real Sun at *F*, than from *H* to *k* under the fictitious Sun at *f*; and conſequently it will then be noon by the Sun-dial ſooner than by the Clock.

As the real Sun moves from *A* toward *C*, the ſwiftneſs of his motion increaſes all the way to *C*, where it is at the quickeſt. But notwithſtanding this, the fictitious Sun gains ſo much upon the real ſoon after his departing from *A*, that the increaſing velocity of the real Sun does not bring him up with the equally moving fictitious Sun till the former comes to *C*, and the latter to *c*, when each has gone half round its reſpective Orbit; and then being in conjunction, the Meridian *E H* revolving to *E K* comes to both Suns at the ſame time, and therefore it is noon by them both at the ſame moment.

But the increaſed velocity of the real Sun, now being at the quickeſt, carries him before the fictitious one; and, therefore, the ſame Meridian will come to the fictitious Sun ſooner than to the real; for while the fictitious Sun moves from *c* to *g*,

 the

PLATE VI. the real Sun moves through a greater arc from *C* to *G*: consequently the point *K* has its noon by the Clock when it comes to *k*, but not its noon by the Sun till it comes to *l*. And although the velocity of the real Sun diminishes all the way from *C* to *A*, and the fictitious Sun by an equable motion is still coming nearer to the real Sun, yet they are not in conjunction till the one comes to *A*, and the other to *a*; and then it is noon by them both at the same moment.

Thus it appears, that the solar noon is always later than noon by the clock while the Sun goes from *C* to *A*, sooner while he goes from *A* to *C*, and at these two points the Sun and Clock being equal, it is noon by them both at the same moment.

Apogee, Perigee, and Apsides, what.

238. The point *A* is called *the Sun's Apogee*, because when he is there, he is at his greatest distance from the Earth; the point *C* his *Perigee*, because when in it he is at his least distance from the Earth: and a right line, as *AEC*, drawn through the Earth's center, from one of these points to the other, is called *the line of the Apsides*.

Fig. IV.

239. The distance that the Sun has gone in any time from his Apogee (not the distance he has to go to it, though ever so little) is called *his mean Anomaly*, and is reckoned in Signs and Degrees, allowing 30 Degrees to a Sign. Thus, when the Sun has gone 174 Degrees from his Apogee at *A*, he is said to be 5 Signs 24 Degrees from it, which is his mean Anomaly; and when he is gone 355 Degrees from his Apogee, he is said to be 11 Signs 25 Degrees from it, although he be but 5 Degrees short of *A* in coming round to it again.

Mean Anomaly, what.

240. From what was said above, it appears, that when the Sun's Anomaly is less than 6 Signs, that is, when he is any where between *A* and *C*, in the half *ABC* of its Orbit, the solar noon precedes

cedes the clock noon; but when his Anomaly is more than 6 Signs, that is, when he is any where between *C* and *A*, in the half *C D A* of his Orbit, the clock noon precedes the ſolar. When his Anomaly is 0 Signs, 0 Degrees, that is, when he is in his Apogee at *A*; or 6 Signs 0 Degrees, which is when he is in his Perigee at *C*; he comes to the Meridian at the moment that the fictitious Sun does, and then it is noon by them both at the ſame inſtant.

241. The following Table ſhews the Variation, or Equation of time depending on the Sun's Anomaly, and ariſing from his unequal motion in the Ecliptic; as the former Table, § 229, ſhews the Variation depending on the Sun's place, and reſulting from the obliquity of the Ecliptic: this is to be underſtood the ſame way as the other, namely, that when the Signs are at the head of the Table, the Degrees are at the left hand; but when the Signs are at the foot of the Table, the reſpective Degrees are at the right hand; and in both caſes the Equation is in the Angle of meeting. When both the above-mentioned Equations are either faſter or ſlower, their ſum is the abſolute Equation of Time; but when the one is faſter, and the other ſlower, it is their difference. Thus, ſuppoſe the Equation depending on the Sun's place be 6 minutes 41 ſeconds too ſlow, and the Equation depending on the Sun's Anomaly be 4 minutes 20 ſeconds too ſlow, their ſum is eleven minutes one ſecond too ſlow. But if the one had been 6 minutes 41 ſeconds too faſt, and the other 4 minutes 20 ſeconds too ſlow, their difference would have been 2 minutes 21 ſeconds too faſt, becauſe the greater quantity is too faſt.

A Table of the Equation of Time, depending on the Sun's Anomaly.

	Sun faster than the Clock if his Anomaly be												
	0 Signs.		1		2		3		4		5		
D.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	
0	0	0	3	47	6	36	7	43	6	45	3	56	30
1	0	8	3	54	6	40	7	43	6	41	3	49	29
2	0	16	4	1	6	44	7	43	6	37	3	41	28
3	0	24	4	8	6	48	7	43	6	32	3	34	27
4	0	32	4	14	6	52	7	42	6	28	3	27	26
5	0	40	4	21	6	56	7	42	6	24	3	19	25
6	0	47	4	27	6	59	7	41	6	19	3	12	24
7	0	55	4	34	7	2	7	40	6	14	3	4	23
8	1	3	4	40	7	6	7	39	6	9	2	57	22
9	1	11	4	47	7	9	7	38	6	4	2	49	21
10	1	19	4	53	7	12	7	37	5	59	2	41	20
11	1	27	4	59	7	14	7	36	5	54	2	34	19
12	1	34	5	5	7	17	7	35	5	49	2	26	18
13	1	42	5	11	7	20	7	33	5	43	2	18	17
14	1	50	5	17	7	22	7	31	5	38	2	10	16
15	1	57	5	22	7	24	7	29	5	32	2	2	15
16	2	5	5	28	7	27	7	27	5	26	1	54	14
17	2	13	5	34	7	29	7	25	5	20	1	46	13
18	2	20	5	39	7	31	7	23	5	14	1	38	12
19	2	28	5	44	7	32	7	20	5	8	1	30	11
20	2	35	5	50	7	34	7	18	5	2	1	22	10
21	2	43	5	55	7	35	7	15	4	56	1	14	9
22	2	50	6	0	7	37	7	12	4	50	1	6	8
23	2	57	6	5	7	38	7	9	4	43	0	58	7
24	3	5	6	10	7	39	7	6	4	37	0	49	6
25	3	12	6	14	7	40	7	3	4	30	0	41	5
26	3	19	6	19	7	41	7	0	4	23	0	33	4
27	3	26	6	24	7	41	6	56	4	17	0	25	3
28	3	33	6	28	7	42	6	53	4	10	0	17	2
29	3	40	6	32	7	42	6	49	4	3	0	8	1
30	3	47	6	36	7	43	6	45	3	56	0	0	0
	11 Signs		10		9		8		7		6		D.
	Sun slower than the Clock if his Anomaly be												

This Table is ſormed by turning the Equation of the Sun's Center (ſee p. 316) into time.

242. The obliquity of the Ecliptic to the Equator, which is the firſt mentioned cauſe of the Equation of Time, would make the Sun and Clocks agree on four days of the year; which are, when the Sun enters Aries, Cancer, Libra, and Capricorn: but the other cauſe, now explained, would

would make the Sun and Clocks equal only twice in a year; that is, when the Sun is in his Apogee and Perigee. Consequently, when these two points fall in the beginnings of Cancer and Capricorn, or of Aries and Libra, they concur in making the Sun and Clocks equal in these points. But the Apogee at present is in the 9th degree of Cancer, and the Perigee in the 9th degree of Capricorn; and therefore the Sun and Clocks cannot be equal about the beginnings of these Signs, nor at any time of the year, except when the swiftness or slowness of the Equation resulting from one cause just balances the slowness or swiftness arising from the other.

243. The second Table in the following Chapter shews the Sun's place in the Ecliptic at the noon of every day by the Clock, for the second year after Leap-year; and also the Sun's Anomaly to the nearest degree, neglecting the odd minutes of that degree. Its use is only to assist in the method of making a general Equation Table from the two fore-mentioned Tables of Equation depending on the Sun's Place and Anomaly, § 229, 241; concerning which method we shall give a few examples presently. The next Tables which follow them are made from those two; and shew the absolute Equation of Time resulting from the combination of both its causes; in which the minutes as well as degrees, both of the Sun's Place and Anomaly, are considered. The use of these Tables is already explained, § 225: and they serve for every day in Leap-year, and the first, second, and third years after: For on most of the same days of all these years the Equation differs, because of the odd six hours more than the 365 days of which the year consists.

Example I. On the 14th of *April*, the Sun is in the 25th degree of ♈ Aries, and his Anomaly is 9 Signs 15 degrees; the Equation resulting Examples for making Equation Tables.

 from

from the former is 7 minutes 22 ſeconds of time too faſt, § 229; and from the latter, 7 minutes 24 ſeconds too ſlow, § 241; the difference is 2 ſeconds that the Sun is too ſlow at the noon of that day, taking it in groſs for the degrees of the Sun's Place and Anomaly, without making proportionable allowance for the odd minutes. Hence, at noon, the ſwiftneſs of the one Equation balancing ſo nearly the ſlowneſs of the other, makes the Sun and Clocks equal on ſome part of that day.

Example II. On the 16th of *June*, the Sun is in the 25th degree of ♊ Gemini, and his Anomaly is 11 Signs 16 Degrees; the Equation ariſing from the former is 1 minute 48 ſeconds too faſt; and from the latter 1 minute 50 ſeconds too ſlow; which balancing one another at noon to 2 ſeconds, the Sun and Clocks are again equal on that day.

Example III. On the 31ſt of *Auguſt*, the Sun's place is 8 degrees 11 minutes of ♍ Virgo (which we call the 8th degree, as it is ſo near), and his Anomaly is 1 Sign 29 Degrees; the Equation ariſing from the former is 6 minutes 40 ſeconds too ſlow; and from the latter 6 minutes 32 ſeconds too faſt; the difference being only 8 ſeconds too ſlow at noon, and decreaſing toward an equality, will make the Sun and Clocks equal in the evening of that day.

Example IV. On the 23d of *December*, the Sun's place is 1 degree 58 minutes (call it 2 degrees) of ♑ Capricorn, and his Anomaly is 5 Signs 23 Degrees; the Equation for the former is 43 ſeconds too ſlow, and for the latter 58 ſeconds too faſt; the difference is 15 ſeconds too faſt at noon; which decreaſing will come to an equality, and ſo make the Sun and Clocks equal in the evening of that day.

And

And thus we find, that on ſome part of each of the above-mentioned four days, the Sun and Clocks are equal; but if we work examples for all other days of the year, we ſhall find them different. And,

244. On thoſe days which are equidiſtant from any Equinox or Solſtice, we do not find that the Equation is as much too faſt or too ſlow on the one ſide, as it is too ſlow or too faſt on the other. The reaſon is, that the line of the Apſides, § 238, does not, at preſent, fall either into the Equinoctial or Solſtitial points, § 242. Remark.

245. The four following Equation Tables, for Leap-year, and the firſt, ſecond, and third years after, would ſerve for ever, if the Sun's Place and Anomaly were always the ſame on every given day of the year as on the ſame day four years before or after. But ſince that is not the caſe, no general Equation Tables can be ſo conſtructed as to be perpetual. The Reaſon why Equation Tables are but temporary.

CHAP. XIV.

Of the Preceſſion of the Equinoxes.

246. IT has been already obſerved, § 116, that by the Earth's motion on its Axis, there is more matter accumulated all around the equatorial parts than any where elſe on the Earth.

The Sun and Moon, by attracting this redundancy of matter, bring the Equator ſooner under them in every return towards it, than if there was no ſuch accumulation. Therefore, if the Sun ſets out, from any Star, or other fixed point in the Heavens, the moment when he is departing from the Equinoctial or from either Tropic, he will come to the ſame Equinox or Tropic again 20 min. 17½ ſec. of time, or 50 ſeconds of a degree, before he completes his courſe, ſo as to arrive at the ſame fixed Star or Point from whence he ſet out. For

PLATE VI. the Equinoctial points recede 50 ſeconds of a degree weſtward every year, contrary to the Sun's annual progreſſive motion.

When the Sun arrives at the ſame * Equinoctial or Solſtitial point, he finiſhes what we call the *Tropical Year*; which, by obſervation, is found to contain 365 days 5 hours 48 minutes 57 ſeconds: and when he arrives at the ſame fixed Star again, as ſeen from the Earth, he completes the *Sydereal Year*, which contains 365 days 6 hours 9 minutes 14½ ſeconds. The *Sydereal Year* is therefore 20 minutes 17½ ſeconds longer than the Solar or Tropical Year, and 9 minutes 14½ ſeconds longer than the Julian or Civil year, which we ſtate at 365 days 6 hours: ſo that the Civil year is almoſt a mean betwixt the Sydereal and Tropical.

247. As the Sun deſcribes the whole Ecliptic, or 360 degrees, in a Tropical year, he moves 59′ 8″ of a degree every day at a mean rate: and conſequently 50″ of a degree in 20 minutes 17½ ſeconds of time: therefore he will arrive at the ſame Equinox or Solſtice when he is 50″ of a degree ſhort of the ſame Star or fixed point in the Heavens from which he ſet out in the year before. So that with reſpect to the fixed Stars, the Sun and Equinoctial points fall back (as it were) 30 degrees in 2160 years, which will make the Stars appear to have gone 30 deg. forward, with reſpect to the Signs of the Ecliptic in that time: for the ſame Signs always keep in the ſame points of the Ecliptic, without regard to the Conſtellations.

Fig. IV. To explain this by a Figure, let the Sun be in Conjunction with a fixed Star at *S*, ſuppoſe in the 30th degree of ♉, on the 21ſt day of *May* 1756. Then making 2160 revolutions through the Eclip-

* The two oppoſite points in which the Ecliptic croſſes the Equinoctial, are called *the Equinoctial points*: and the two points where the Ecliptic touches the Tropics (which are likewiſe oppoſite, and 90 degrees from the former) are called *the Solſtitial points.*

tic

A TABLE shewing the Precession of the Equinoctial Points in the Heavens, both in Motion and Time; and the Anticipation of the Equinoxes on the Earth.

Julian years.	Precession of the Equinoctial Points in the Heavens. Motion.				Time.				Anticipation of the Equinoxes on the Earth.			
	s	°	'	"	Days	H.	M.	S.	D.	H.	M.	S.
1	0	0	0	50	0	0	20	17½	0	0	11	3
2	0	0	1	40	0	0	40	35	0	0	22	6
3	0	0	2	30	0	1	0	52½	0	0	33	9
4	0	0	3	20	0	1	21	10	0	0	44	12
5	0	0	4	10	0	1	41	27½	0	0	55	15
6	0	0	5	0	0	2	1	45	0	1	6	18
7	0	0	5	50	0	2	22	2½	0	1	17	21
8	0	0	6	40	0	2	42	20	0	1	28	24
9	0	0	7	30	0	3	2	37½	0	1	39	27
10	0	0	8	20	0	3	22	55	0	1	50	30
20	0	0	16	40	0	6	45	50	0	3	41	0
30	0	0	25	0	0	10	8	45	0	5	31	30
40	0	0	33	20	0	13	31	40	0	7	22	0
50	0	0	41	40	0	16	54	35	0	9	12	30
60	0	0	50	0	0	20	17	30	0	11	3	0
70	0	0	58	20	0	23	40	25	0	12	53	30
80	0	1	6	40	1	3	3	20	0	14	44	0
90	0	1	15	0	1	6	20	15	0	16	34	30
100	0	1	23	20	1	9	49	10	0	18	25	0
200	0	2	46	40	2	19	38	20	1	12	50	0
300	0	4	10	0	4	5	27	30	2	7	15	0
400	0	5	33	20	5	15	16	40	3	1	40	0
500	0	6	56	40	7	1	5	50	3	20	5	0
600	0	8	20	0	8	10	55	0	4	14	30	0
700	0	9	43	20	9	20	44	10	5	8	55	0
800	0	11	6	40	11	6	33	20	6	3	20	0
900	0	12	30	0	12	16	22	30	6	21	45	0
1000	0	13	53	20	14	2	11	40	7	16	10	0
2000	0	27	46	40	28	4	23	20	15	8	20	0
3000	1	11	40	0	42	6	35	0	23	0	30	0
4000	1	25	33	20	56	8	40	40	30	10	40	0
5000	2	9	26	40	70	10	58	20	38	8	50	0
6000	2	23	20	0	84	13	10	0	46	1	0	0
7000	3	7	13	20	98	15	21	40	53	17	10	0
8000	3	21	6	40	112	17	33	20	61	9	20	0
9000	4	5	0	0	126	19	45	0	69	1	30	0
10000	4	18	53	20	140	21	56	40	76	17	40	0
20000	9	7	46	40	281	19	53	20	153	11	20	0
25920	12	0	0	0	365	6	0	0	198	21	36	0

tic *VWX*, at the end of ſo many Sydereal years, he will be found again at *S*: but at the end of ſo many Julian years, he will be found at *M*, ſhort of *S*, and at the end of ſo many Tropical years, he will be found ſhort of *M*, in the 30th deg. of Taurus at *T*, which has receded back from *S* to *T* in that time, by the preceſſion of the Equinoctial points ♈ *Aries* and ♎ *Libra*. The Arc *ST* will be equal to the amount of the preceſſion of the Equinox in 2160 years at the rate of 50″ of a degree, or 20 min. 17½ ſec. of time annually: this, in ſo many years, makes 30 days 10½ hours: which is the difference between 2160 Sydereal and Tropical years. And the Arc *MT* will be equal to the ſpace moved through by the Sun in 2160 times 11 min. 3 ſec. or 16 days 13 hours 48 minutes, which is the difference between 2160 Julian and Tropical years.

248. From the ſhifting of the Equinoctial points, and with them all the Signs of the Ecliptic, it follows that thoſe Stars which in the infancy of Aſtronomy were in *Aries* are now got into *Taurus*; thoſe of *Taurus* into *Gemini*, &c. Hence likewiſe it is, that the Stars which roſe or ſet at any particular ſeaſon of the year, in the times of HESIOD, EUDOXUS, VIRGIL, PLINY, &c. by no means anſwer at this time to their deſcriptions. The preceding Table ſhews the quantity of this ſhifting both in the Heavens and on the Earth, for any number of years to 25,920; which completes the grand celeſtial period: within which any number and its quantity is eaſily found, as in the following example, for 5763 years; which at the Autumnal Equinox, *A. D.* 1756, is thought to be the age of the world. So that with regard to the fixed Stars, the Equinoctial points in the Heavens, have receded $2^s\ 20^\circ\ 2'\ 30''$ ſince the creation; which is as much as the Sun moves in $81^d\ 5^h\ 0^m\ 52^s$. And ſince that time, or in 5763 years, the Equinoxes with us

us have fallen back $44^d\ 5^h\ 21^m\ 9^s$; hence, reckoning from the time of the *Julian* Equinox, *A. D.* 1756, *viz. Sept.* 11th, it appears that the Autumnal Equinox at the creation was on the 25th of *October*.

Julian years.	Precession of the Equinoctial Points in the Heavens.								Anticipation of the Equinoxes on the Earth.			
	Motion.				Time.							
	s	o	′	″	D.	H.	M.	S.	D.	H.	M.	S.
5000	2	9	26	40	70	10	58	20	38	8	50	0
700	0	9	43	20	9	20	44	10	5	8	55	0
60	0	0	50	0	0	20	17	30	0	11	3	0
3	0	0	2	30	0	1	0	52	0	0	33	9
5763	2	20	2	30	81	5	0	52	44	5	21	9

249. The anticipation of the Equinoxes, and consequently of the Seasons, is by no means owing to the precession of the Equinoctial and Solstitial points in the Heavens (which can only affect the apparent motions, places, and declinations of the fixed Stars), but to the difference between the Civil and Solar year, which is 11 minutes 3 seconds; the Civil year containing 365 days 6 hours, and the Solar year 365 days 5 hours 48 minutes 57 seconds. The next following Table, page 159, shews the length, and consequently the difference of any number of Sydereal, Civil, and Solar years from 1 to 10,000.

The Anticipation of the Equinoxes and Seasons.

250. The above 11 minutes 3 seconds, by which the Civil or Julian year exceeds the Solar, amounts to 11 days in 1433 years: and so much our seasons have fallen back with respect to the days of the months, since the time of the *Nicene* Council in *A. D.* 325, and therefore, in order to bring back all the Fasts and Festivals to the days then settled, it

The reason for altering the Style.

PLATE VI. it was requiſite to ſuppreſs 11 nominal days. And that the ſame ſeaſons might be kept to the ſame times of the year for the future, to leave out the Biſſextile day in *February* at the end of every century of years where the ſignificant figures are not diviſible by 4; reckoning them only common years, as the 17th, 18th, and 19th centuries, *viz.* the years 1700, 1800, 1900, &c. becauſe a day intercalated every fourth year was too much, and retaining the Biſſextile-day at the end of thoſe Centuries of years which are diviſible by 4, as the 16th, 20th, and 24th, Centuries; *viz.* the years 1600, 2000, 2400, &c. Otherwiſe, in length of time, the ſeaſons would be quite reverſed with regard to the months of the year; though it would have required near 23,783 years to have brought about ſuch a total change. If the Earth had made exactly 365¼ diurnal rotations on its Axis, while it revolved from any Equinoctial or Solſtitial point to the ſame again, the Civil and Solar years would always have kept pace together, and the Style would never have required any alteration.

The Preceſſion of the Equinoctial points. 251. Having already mentioned the cauſe of the Preceſſion of the Equinoctial points in the Heavens, § 246, which occaſions a ſlow deviation of the Earth's axis from its paralleliſm, and thereby a change of the declination of the Stars from the Equator, together with a ſlow apparent motion of the Stars forward with reſpect to the Signs of the Ecliptic, we ſhall now explain the Phenomena by a Diagram.

Fig. VI. Let *NZSVL* be the Earth, *SONA* its Axis produced to the ſtarry Heavens, and terminating in *A*, the preſent north Pole of the Heavens, which is vertical to *N* the north Pole of the Earth. Let *EOQ* be the Equator, *T* ♋ *Z* the Tropic of Cancer, and *VT* ♑ the Tropic of Capricorn: *VOZ* the Ecliptic, and *BO* its Axis, both which are immoveable

able among the Stars. But, as * the Equinoctial points recede in the Ecliptic, the Earth's Axis *SON* is in motion upon the Earth's center *O*, in ſuch a manner, as to deſcribe the double Cone *NOn* and *SOs*, round the Axis of the Ecliptic *BO*, in the time that the Equinoctial points move quite round the Ecliptic, which is 25,920 years; and in that length of time the north Pole of the Earth's Axis produced, deſcribes the Circle *ABCDA* in the ſtarry Heavens, round the Pole of the Ecliptic, which keeps immoveable in the center of that Circle. The Earth's Axis being 23½ degrees inclined to the Axis of the Ecliptic, the Circle *ABCDA*, deſcribed by the north Pole of the Earth's Axis produced to *A*, is 47 degrees in diameter, or double the inclination of the Earth's Axis. In conſequence of this motion, the point *A*, which at preſent is the north Pole of the Heavens, and near to a ſtar of the ſecond magnitude in the tail of the conſtellation called *the Little Bear*, muſt be deſerted by the Earth's Axis; which moving backward a degree every 72 years, will be directed toward the Star or point *B* in 6480 years from this time: and in twice that time, or 12,960 years, it will be directed toward the Star or Point *C*; which will then be the north Pole of the Heavens, although it is at preſent 8½ degrees ſouth of the Zenith of *London L*. The preſent poſition of the Equator *EOQ*, will then be changed into *eOq*, the Tropic of Cancer *T*♋*Z* into *Vt*♋, and the Tropic of Capricorn *VT*♑ into *t*♑*Z*; as is evident by the Figure; and the Sun, when in that part of the Heavens where he is now over the

* The Equinoctial Circle interſects the Ecliptic in two oppoſite points; namely, the firſt points of the ſigns *Aries* and *Libra*: They are called the Equinoctial Points, becauſe when the Sun is in either of them, he is directly over the terreſtrial Equator; and then the days and nights are equal.

earthly Tropic of Capricorn, and makes the ſhorteſt days and longeſt nights in the Northern Hemiſphere, will then be over the earthly Tropic of Cancer, and make the days longeſt and nights ſhorteſt. And it will require 12,960 years more, or 25,920 from the preſent time, to bring the north Pole *N* quite round, ſo as to be directed toward that point of the Heavens which is vertical to it at preſent. And then, and not till then, the ſame Stars, which at preſent deſcribe the Equator, Tropics, and Polar Circles, &c. by the Earth's diurnal motion, will deſcribe them over again.

A TABLE

A TABLE shewing the Time contained in any number of Sydereal, Julian, and Solar Years, from 1 to 10000.

	Sydereal Years.				Julian Years.		Solar Years.			
Years.	Days.	H.	M.	S.	Days.	H.	Days.	H.	M.	S.
1	365	6	9	14½	365	6	365	5	48	57
2	730	12	18	29	730	12	730	11	37	54
3	1095	18	27	43½	1095	18	1095	17	26	51
4	1461	0	36	58	1461	0	1460	23	15	48
5	1826	6	46	12½	1826	6	1826	5	4	45
6	2191	12	55	27	2191	12	2191	10	53	42
7	2556	19	5	41½	2556	18	2556	16	42	39
8	2922	1	13	56	2922	0	2921	22	31	36
9	3287	7	23	10½	3287	6	3287	4	20	33
10	3652	13	32	25	3652	12	3652	10	9	30
20	7305	3	4	50	7305	0	7304	20	19	0
30	10957	16	37	15	10957	12	10957	6	28	30
40	14610	6	9	40	14610	0	14609	16	38	0
50	18262	19	42	5	18262	12	18262	2	47	0
60	21915	9	14	30	21915	6	21914	12	57	0
70	25567	22	46	55	25567	12	25566	23	6	30
80	29220	12	19	20	29220	0	29219	9	16	0
90	32873	1	51	45	32872	12	32871	19	25	30
100	36525	15	24	10	36525		36524	5	35	
200	73051	6	48	20	73050		73048	11	10	
300	109576	22	12	30	109575		109572	16	45	
400	146102	13	36	40	146100		146096	22	20	
500	182628	5	0	50	182625		182621	3	55	
600	219153	20	25		219150		219145	9	30	
700	255679	11	49	10	255675		255669	15	5	
800	292205	3	13	20	292200		292193	20	40	
900	228730	18	37	30	328725		328718	2	15	
1000	365256	10	1	40	365250		365242	7	50	
2000	730512	20	3	20	730500		730484	15	40	
3000	1095769	6	5		1095750		1095726	23	30	
4000	1461025	16	6	40	1461000		1460969	7	20	
5000	1826282	2	8	20	1826250		1826211	15	10	
6000	2191538	12	10		2191500		2191453	23	0	
7000	2556794	22	11	40	2556750		2556696	6	50	
8000	2952051	8	13	20	2922000		2921938	14	40	
9000	3287037	18	15		3287250		3287180	22	30	
10000	3652564	4	16	40	3652500		3652423	6	20	

A TABLE ſhewing the Sun's true Place, and Diſtance from its Apogee, for the ſecond Year after Leap-year.

Days.	January.		February.		March.		April.	
	Sun's Place.	Sun's Anom.	Sun's Place.	Sun's Anom.	Sun's Place.	Sun's Anom.	Sun's Place.	Sun's Anom.
	D. M	D. M.	D. M.	D. M.	D. M	D. M.	D. M.	D. M.
1	11 ♑ 23	6 2	12 ♒ 56	7 4	11 ♓ 10	8 2	11 ♈ 57	9 3
2	12 24	6 3	13 57	7 5	12 10	8 3	12 56	9 4
3	13 25	6 4	14 58	7 6	13 10	8 4	13 55	9 5
4	14 27	6 5	15 58	7 7	14 10	8 5	14 54	9 6
5	15 28	6 6	16 59	7 8	15 10	8 6	15 53	9 7
6	16 29	6 7	18 00	7 9	16 10	8 7	16 52	9 8
7	17 30	6 8	19 01	7 10	17 10	8 8	17 51	9 8
8	18 31	6 9	20 01	7 11	18 10	8 9	18 49	9 9
9	19 32	6 10	21 02	7 12	19 09	8 10	19 48	9 10
10	20 34	6 11	22 03	7 13	20 09	8 11	20 47	9 11
11	21 35	6 12	23 03	7 14	21 09	8 12	21 46	9 12
12	22 36	6 13	24 04	7 15	22 09	8 13	22 44	9 13
13	23 37	6 14	25 04	7 16	23 09	8 14	23 43	9 14
14	24 38	6 15	26 05	7 17	24 08	8 15	24 42	9 15
15	25 39	6 16	27 06	7 18	25 08	8 16	25 40	9 16
16	26 40	6 17	28 06	7 19	26 08	8 17	26 39	9 17
17	27 42	6 18	29 07	7 20	27 07	8 18	27 38	9 18
18	28 43	6 19	♓ 07	7 21	28 07	8 19	28 36	9 19
19	29 44	6 20	1 07	7 22	29 06	8 20	29 35	9 20
20	♒ 45	6 21	2 08	7 23	♈ 06	8 21	♉ 33	9 21
21	1 46	6 22	3 08	7 24	1 05	8 22	1 32	9 22
22	2 47	6 23	4 08	7 25	2 05	8 23	2 30	9 23
23	3 48	6 24	5 09	7 26	3 04	8 24	3 28	9 24
24	4 49	6 25	6 09	7 27	4 03	8 25	4 27	9 25
25	5 50	6 26	7 09	7 28	5 03	8 26	5 25	9 26
26	6 51	6 28	8 09	7 29	6 02	8 27	6 23	9 27
27	7 52	6 29	9 10	8 0	7 01	8 28	7 21	9 28
28	8 53	7 0	10 10	8 1	8 00	8 29	8 20	9 29
29	9 53	7 1			9 00	9 0	9 18	10 0
30	10 54	7 2			9 59	9 1	10 16	10 1
31	11 55	7 3			10 58	9 2		

A TABLE shewing the Sun's true Place, and Distance from its Apogee, for the second Year after Leap-year.

Days.	May.				June.				July.				August.			
	Sun's Place.		Sun's Anom.		Sun's Place.		Sun's Anom.		Sun's Place.		Sun's Anom.		Sun's Place.		Sun's Anom.	
	D.	M.	S.	D.	D.	M.	S.	D.	D.	M.	S.	D.	D.	M.	S.	D.
1	11 ♉	14	10	2	11 ♊	04	11	2	9 ♋	42	0	0	9 ♌	18	1	0
2	12	12	10	3	12	01	11	3	10	39	0	1	10	16	1	1
3	13	10	10	4	12	59	11	4	11	37	0	2	11	13	1	2
4	14	08	10	5	13	56	11	5	12	34	0	3	12	11	1	3
5	15	06	10	6	14	53	11	6	13	31	0	4	13	08	1	4
6	16	04	10	7	15	51	11	6	14	28	0	5	14	06	1	5
7	17	02	10	8	16	48	11	7	15	25	0	6	15	03	1	6
8	18	00	10	9	17	46	11	8	16	23	0	7	16	01	1	7
9	18	58	10	10	18	43	11	9	17	20	0	8	16	58	1	8
10	19	56	10	11	19	40	11	10	18	17	0	9	17	56	1	9
11	20	54	10	12	20	38	11	11	19	14	0	10	18	54	1	10
12	21	52	10	12	21	35	11	12	20	12	0	11	19	51	1	10
13	22	49	10	13	22	32	11	13	21	09	0	12	20	49	1	11
14	23	47	10	14	23	30	11	14	22	06	0	13	21	47	1	12
15	24	45	10	15	24	27	11	15	23	03	0	14	22	44	1	13
16	25	43	10	16	25	24	11	16	24	01	0	15	23	42	1	14
17	26	41	10	17	26	21	11	17	24	58	0	16	24	40	1	15
18	27	38	10	18	27	19	11	18	25	55	0	17	25	38	1	16
19	28	36	10	19	28	16	11	19	26	53	0	18	26	36	1	17
20	29	34	10	20	29	13	11	20	27	50	0	18	27	33	1	18
21	♊	31	10	21	♋	10	11	21	28	47	0	19	28	31	1	19
22	1	29	10	22	1	08	11	22	29	44	0	20	29	29	1	20
23	2	26	10	23	2	05	11	23	♌	42	0	21	♍	27	1	21
24	3	24	10	24	3	02	11	24	1	39	0	22	1	25	1	22
25	4	22	10	25	3	59	11	25	2	36	0	23	2	23	1	23
26	5	19	10	26	4	56	11	26	3	34	0	24	3	21	1	24
27	6	17	10	27	5	53	11	27	4	31	0	25	4	19	1	25
28	7	14	10	28	6	51	11	27	5	28	0	26	5	17	1	26
29	8	12	10	29	7	48	11	28	6	26	0	27	6	15	1	27
30	9	09	11	0	8	45	11	29	7	23	0	28	7	13	1	28
31	10	06	11	1					8	21	0	29	8	11	1	29

A TABLE shewing the Sun's true Place, and Distance from its Apogee, for the second Year after Leap-Year.

Days.	September.				October.				November.				December.			
	Sun's Place.		Sun's Anom.		Sun's Place.		Sun's Anom.		Sun's Place.		Sun's Anom.		Sun's Place.		Sun's Anom.	
	D.	M.	S.	D.	D.	M.	S.	D.	D.	M.	S.	D	D.	M.	S.	D.
1	9 ♍	09	2	0	8 ♎	28	2	29	9 ♏	17	4	0	9 ♐	34	5	0
2	10	07	2	1	9	27	3	0	10	17	4	1	10	35	5	1
3	11	05	2	2	10	26	3	1	11	17	4	2	11	36	5	2
4	12	04	2	3	11	25	3	2	12	18	4	3	12	37	5	3
5	13	02	2	4	12	25	3	3	13	18	4	4	13	38	5	4
6	14	00	2	5	13	24	3	4	14	18	4	5	14	39	5	5
7	14	59	2	6	14	23	3	5	15	19	4	6	15	40	5	6
8	15	57	2	7	15	23	3	6	16	19	4	7	16	41	5	7
9	16	55	2	8	16	22	3	7	17	19	4	8	17	42	5	8
10	17	54	2	9	17	21	3	8	18	20	4	9	18	43	5	9
11	18	52	2	9	18	21	3	9	19	20	4	10	19	44	5	10
12	19	51	2	10	19	20	3	10	20	21	4	11	20	45	5	11
13	20	49	2	11	20	20	3	11	21	22	4	12	21	46	5	12
14	21	48	2	12	21	20	3	12	22	23	4	13	22	47	5	13
15	22	46	2	13	22	19	3	13	23	22	4	14	23	49	5	14
16	23	45	2	14	23	19	3	14	24	23	4	15	24	50	5	15
17	24	44	2	15	24	18	3	15	25	23	4	16	25	51	5	16
18	25	42	2	16	25	18	3	16	26	24	4	17	26	52	5	17
19	26	41	2	17	26	18	3	17	27	25	4	18	27	53	5	19
20	27	40	2	18	27	18	3	18	28	25	4	19	28	54	5	20
21	28	39	2	19	28	17	3	19	29	26	4	20	29	55	5	21
22	29	37	2	20	29	17	3	20	♐	27	4	21	♑	56	5	22
23	♎	36	2	21	♏	17	3	21	1	27	4	22	1	58	5	23
24	1	35	2	22	1	17	3	22	2	28	4	23	2	59	5	24
25	2	34	2	23	2	17	3	23	3	29	4	24	4	00	5	25
26	3	33	2	24	3	17	3	24	4	30	4	25	5	01	5	26
27	4	32	2	25	4	17	3	25	5	30	4	26	6	02	5	27
28	5	31	2	26	5	17	3	26	6	31	4	27	7	03	5	28
29	6	30	2	27	6	17	3	27	7	32	4	28	8	05	5	29
30	7	29	2	28	7	17	3	28	8	33	4	29	9	06	6	0
31					8	17	3	29					10	07	6	1

TABLES

TABLES

OF THE

EQUATION OF TIME,

FOR

LEAP-YEARS AND COMMON YEARS;

Shewing what Time it ought to be by the CLOCK when the SUN's Center is on the Meridian.

A TABLE ſhewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The Biſſextile, or Leap-Year.

Days.	January.			February.			March.			April.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XII	4	02	XII	14	3	XII	12	30	XII	3	42
2		4	30		14	10		12	17		3	24
3		4	58		14	17		12	4		3	6
4		5	25		14	22		11	50		2	48
5		5	52		14	27		11	35		2	30
6	XII	6	19	XII	14	31	XII	11	21	XII	2	13
7		6	45		14	34		11	6		1	55
8		7	10		14	37		10	50		1	38
9		7	35		14	38		10	34		1	21
10		8	0		14	39		10	18		1	4
11	XII	8	24	XII	14	39	XII	10	2	XII	0	48
12		8	47		14	38		9	45		0	32
13		9	10		14	37		9	28		0	17
14		9	32		14	35		9	11		0	1
15		9	53		14	32		8	54	XI	59	47
16	XII	10	14	XII	14	28	XII	8	36	XI	59	32
17		10	34		14	24		8	18		59	18
18		10	53		14	19		8	0		59	4
19		11	12		14	13		7	42		58	51
20		11	30		14	7		7	24		58	38
21	XII	11	47	XII	14	0	XII	7	6	XI	58	26
22		12	3		13	52		0	47		58	14
23		12	19		13	44		6	29		58	2
24		12	34		13	35		6	10		57	51
25		12	48		13	26		5	52		57	41
26	XII	13	0	XII	13	16	XII	5	33	XI	57	31
27		13	13		13	5		5	15		57	21
28		13	25		12	54		4	56		57	12
29		13	36		12	42		4	37		57	4
30		13	45					4	19		56	55
31		13	54					4	0			

A TABLE ſhewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The Biſſextile, or Leap-Year.

Days.	May.			June.			July.			Auguſt.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XI	56	48	XI	57	30	XII	3	29	XII	5	51
2		56	41		57	40		3	40		5	47
3		56	34		57	49		3	51		5	42
4		56	28		57	59		4	02		5	36
5		56	23		58	10		4	12		5	30
6	XI	56	18	XI	58	20	XII	4	22	XII	5	23
7		56	14		58	31		4	31		5	16
8		56	10		58	42		4	40		5	2
9		56	7		58	54		4	49		5	0
10		56	5		59	6		4	57		4	51
11	XI	56	3	XI	59	18	XII	5	5	XII	4	41
12		56	1		59	30		5	13		4	31
13		56	0		59	42		5	20		4	21
14		56	0		59	55		5	26		4	10
15		56	01	XII	0	8		5	32		3	58
16	XI	56	2	XII	0	20	XII	5	38	XII	3	46
17		56	4		0	33		5	43		3	33
18		56	6		0	46		5	48		3	20
19		56	9		0	59		5	52		3	7
20		56	12		1	13		5	56		2	52
21	XI	56	16	XII	1	26	XII	5	59	XII	2	38
22		56	20		1	39		6	1		2	23
23		56	25		1	52		6	3		2	7
24		56	31		2	4		6	4		1	52
25		56	36		2	17		6	4		1	35
26	XI	56	43	XII	2	30	XII	6	4	XII	1	18
27		56	50		2	42		6	4		1	1
28		56	57		2	54		6	2		0	44
29		57	5		3	6		6	0		0	26
30		57	13		3	18		5	58		0	8
31		57	21					5	55	XI	59	40

A TABLE ſhewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The Biſſextile, or Leap-Year.

Days.	September.			October.			November.			December.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XI	59	30	XI	49	22	XI	43	45	XI	49	43
2		59	11		49	3		43	45		50	7
3		58	52		48	45		43	45		50	31
4		58	32		48	27		43	47		50	56
5		58	12		48	9		43	49		51	21
6	XI	57	52	XI	47	52	XI	43	53	XI	51	47
7		57	32		47	36		43	57		52	13
8		57	12		47	19		44	2		52	40
9		56	51		47	4		44	8		53	8
10		56	30		46	48		44	14		53	35
11	XI	56	10	XI	46	33	XI	44	22	XI	54	3
12		55	49		46	19		44	30		54	32
13		55	28		46	6		44	40		55	01
14		55	7		45	52		44	50		55	30
15		54	46		45	40		45	1		56	0
16	XI	54	25	XI	45	28	XI	45	13	XI	56	29
17		54	5		45	16		45	25		56	59
18		53	44		45	6		45	39		57	29
19		53	23		44	55		45	53		57	59
20		53	2		44	46		46	8		58	29
21	XI	52	41	XI	44	37	XI	46	24	XI	58	59
22		52	21		44	29		46	41		59	29
23		52	0		44	21		46	58		59	59
24		51	40		44	14		47	16	XII	0	29
25		51	19		44	8		47	35		0	59
26	XI	50	59	XI	44	2	XI	47	55	XII	1	29
27		50	39		43	57		48	15		1	58
28		50	20		43	53		48	36		2	27
29		50	0		43	50		48	58		2	56
30		49	41		43	48		49	20		3	25
31					43	46					3	54

A TABLE ſhewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The firſt Year after Leap-Year.

Days.	January.			February.			March.			April.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XII	4	23	XII	14	9	XII	12	33	XII	3	47
2		4	51		14	16		12	20		3	39
3		5	19		14	21		12	7		3	10
4		5	46		14	27		11	54		2	52
5		6	13		14	31		11	40		2	35
6	XII	6	39	XII	14	34	XII	11	25	XII	2	17
7		7	4		14	37		11	10		2	0
8		7	30		14	39		10	55		1	43
9		7	54		14	40		10	39		1	25
10		8	18		14	40		10	23		1	9
11	XII	8	42	XII	14	39	XII	10	7	XII	0	52
12		9	4		14	38		9	50		0	36
13		9	26		14	36		9	33		0	20
14		9	48		14	33		9	16		0	5
15		10	9		14	30		8	58	XI	59	50
16	XII	10	29	XII	14	25	XII	8	41	XI	59	35
17		10	48		14	20		8	23		59	21
18		11	7		14	15		8	5		59	7
19		11	25		14	9		7	47		58	54
20		11	42		14	2		7	29		58	41
21	XII	11	59	XII	13	54	XII	7	10	XI	58	28
22		12	15		13	46		6	52		58	16
23		12	30		13	37		6	33		58	4
24		12	44		13	28		6	15		57	53
25		12	58		13	18		5	56		57	43
26	XII	13	10	XII	13	8	XII	5	38	XI	57	32
27		13	22		12	57		5	19		57	23
28		13	33		12	45		5	1		57	14
29		13	43					4	42		57	5
30		13	53					4	23		56	57
31		14	1					4	5			

A TABLE shewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The first Year after Leap-Year.

Days.	May.			June.			July.			August.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XI	56	49	XI	57	27	XII	3	26	XII	5	52
2		56	42		57	36		3	37		5	48
3		56	35		57	46		3	48		5	43
4		56	29		57	56		3	58		5	38
5		56	24		58	6		4	9		5	32
6	XI	56	19	XI	58	17	XII	4	19	XII	5	25
7		56	14		58	27		4	28		5	28
8		56	11		58	38		4	37		5	10
9		56	7		58	50		4	46		5	2
10		56	5		59	2		4	55		4	53
11	XI	56	2	XI	59	14	XII	5	3	XII	4	44
12		56	1		59	26		5	10		4	34
13		56	0		59	38		5	17		4	24
14		56	0		59	50		5	24		4	13
15		56	0	XII	0	3		5	30		4	1
16	XI	56	1	XII	0	16	XII	5	36	XII	3	49
17		56	2		0	29		5	41		3	37
18		56	4		0	42		5	46		3	24
19		56	7		0	55		5	50		3	10
20		56	10		1	8		5	54		2	56
21	XI	56	13	XII	1	21	XII	5	57	XII	2	42
22		56	17		1	34		6	0		2	27
23		56	22		1	47		6	2		2	12
24		56	28		2	0		6	3		1	56
25		56	33		2	13		6	4		1	40
26	XII	56	40	XII	2	25	XII	6	4	XII	1	23
27		56	47		2	38		6	4		1	6
28		56	54		2	50		6	3		0	49
29		57	02		3	02		6	1		0	31
30		57	10		3	14		5	59		0	13
31		57	18					5	56	XI	59	55

A TABLE ſhewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The firſt Year after Leap-Year.

Days.	September.			October.			November.			December.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XI	59	36	XI	49	28	XI	43	46	XI	49	38
2		59	17		49	9		43	46		50	01
3		58	58		48	51		43	47		50	25
4		58	38		48	33		43	48		50	50
5		58	18		48	15		43	50		51	15
6	XI	57	58	XI	47	58	XI	43	53	XI	51	41
7		57	38		47	41		43	57		52	7
8		57	18		47	24		44	1		52	34
9		56	57		47	8		44	7		53	01
10		56	37		46	53		44	13		53	28
11	XI	56	16	XI	46	38	XI	44	21	XI	53	56
12		55	55		46	24		44	29		54	25
13		55	34		46	10		44	38		54	54
14		55	13		45	56		44	48		55	23
15		54	52		45	44		44	59		55	52
16	XI	54	31	XI	45	32	XI	45	10	XI	56	22
17		54	11		45	20		45	23		56	51
18		53	50		45	9		45	36		57	21
19		53	29		44	59		45	50		57	51
20		53	8		44	49		46	5		58	21
21	XI	52	47	XI	44	40	XI	46	21	XI	58	51
22		52	27		44	31		46	37		59	22
23		52	6		44	24		46	54		59	52
24		51	46		44	17		47	12	XII	0	22
25		51	25		44	10		47	31		0	52
26	XI	51	5	XI	44	5	XI	47	51	XII	1	21
27		50	45		44	0		48	11		1	51
28		50	26		43	56		48	31		2	20
29		50	6		43	52		48	53		2	50
30		49	47		43	49		49	15		3	19
31					43	47					3	47

A TABLE ſhewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The ſecond Year after Leap-Year.

Days.	January. H.	M.	S.	February. H.	M.	S.	March. H.	M.	S.	April. H.	M.	S.
1	XII	4	15	XII	14	6	XII	12	35	XII	3	50
2		4	43		14	13		12	23		3	32
3		5	11		14	19		12	9		3	14
4		5	38		14	24		11	56		2	56
5		6	5		14	29		11	42		2	38
6	XII	6	31	XII	14	32	XII	11	27	XII	2	20
7		6	57		14	35		11	13		2	3
8		7	22		14	37		10	58		1	46
9		7	47		14	39		10	42		1	29
10		8	12		14	39		10	26		1	12
11	XII	8	35	XII	14	39	XII	10	10	XII	0	56
12		8	58		14	38		9	54		0	40
13		9	21		14	36		9	37		0	24
14		9	43		14	34		9	20		0	9
15		10	4		14	31		9	3	XI	59	54
16	XII	10	24	XII	14	27	XII	8	45	XI	59	39
17		10	44		14	22		8	28		59	25
18		11	3		14	17		8	10		59	11
19		11	22		14	11		7	52		58	58
20		11	39		14	4		7	34		58	45
21	XII	11	56	XII	13	57	XII	7	15	XI	58	32
22		12	12		13	49		6	57		58	20
23		12	27		13	40		6	38		58	8
24		12	41		13	31		6	20		57	56
25		12	55		13	21		6	1		57	45
26	XII	13	7	XII	13	10	XII	5	42	XI	57	35
27		13	19		12	59		5	24		57	25
28		13	30		12	47		5	5		57	15
29		13	40					4	46		57	6
30		13	50					4	27		56	58
31		13	58					4	9			

A TABLE ſhewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The ſecond Year after Leap-Year.

Days.	May.			June.			July.			Auguſt.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XI	56	50	XI	57	24	XII	3	22	XII	5	53
2		56	43		57	33		3	33		5	49
3		56	36		57	42		3	44		5	44
4		56	30		57	52		3	55		5	39
5		56	24		58	3		4	5		5	33
6	XI	56	19	XI	58	13	XII	4	16	XII	5	27
7		56	15		58	24		4	26		5	20
8		56	11		58	35		4	35		5	13
9		56	7		58	47		4	44		5	5
10		56	5		58	59		4	53		4	56
11	XI	56	3	XI	59	11	XII	5	01	XII	4	47
12		56	1		59	23		5	9		4	38
13		56	0		59	37		5	17		4	27
14		56	0		59	48		5	23		4	17
15		56	0	XII	0	01		5	30		4	5
16	XI	56	1	XII	0	14	XII	5	36	XII	3	53
17		56	2		0	27		5	41		3	41
18		56	4		0	40		5	46		3	28
19		56	7		0	53		5	50		3	15
20		56	10		1	6		5	54		3	1
21	XI	56	13	XII	1	19	XII	5	57	XII	2	46
22		56	17		1	31		6	0		2	31
23		56	22		1	44		6	1		2	16
24		56	27		1	57		6	3		2	0
25		56	32		2	10		6	4		1	44
26	XI	56	38	XII	2	22	XII	6	4	XII	1	27
27		56	45		2	34		6	3		1	10
28		56	42		2	46		6	2		0	53
29		56	59		2	58		6	1		0	35
30		57	7		3	10		5	59		0	17
31		57	15					5	56	XI	59	59

A TABLE ſhewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The ſecond Year after Leap-Year.

Days.	September.			October.			November.			December.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XI	59	40	XI	49	32	XI	43	46	XI	49	32
2		59	21		49	14		43	46		49	56
3		59	2		48	55		43	46		50	20
4		58	43		48	37		43	48		50	44
5		58	23		48	20		43	50		51	9
6	XI	58	4	XI	48	3	XI	43	53	XI	51	35
7		57	44		47	46		43	57		52	1
8		57	23		47	29		44	1		52	28
9		57	3		47	14		44	7		52	55
10		56	43		46	58		44	13		53	23
11	XI	56	22	XI	46	43	XI	44	20	XI	53	51
12		56	1		46	29		44	28		54	19
13		55	41		46	15		44	37		54	48
14		55	20		46	1		44	47		55	17
15		54	59		45	48		44	57		55	46
16	XI	54	38	XI	45	36	XI	45	8	XI	56	15
17		54	17		45	24		45	20		56	45
18		53	56		45	13		45	33		57	14
19		53	35		45	2		45	47		57	44
20		53	14		44	52		46	2		58	14
21	XI	52	53	XI	44	42	XI	46	17	XI	58	44
22		52	32		44	34		46	33		59	14
23		52	11		44	26		46	50		59	44
24		51	51		44	18		47	7	XII	0	14
25		51	30		44	11		47	26		0	44
26	XI	51	10	XI	44	6	XI	47	45	XII	1	13
27		50	50		44	0		48	5		1	43
28		50	30		43	56		48	26		2	12
29		50	11		43	52		48	47		2	42
30		49	51		43	50		49	9		3	11
31					43	48					3	40

A TABLE ſhewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The third Year after Leap-Year.

Days.	January.			February.			March.			April.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XII	4	8	XII	14	4	XII	12	38	XII	3	55
2		4	36		14	11		12	25		3	36
3		5	4		14	17		12	12		3	18
4		5	32		14	23		11	59		3	0
5		5	59		14	28		11	45		2	43
6	XII	6	25	XII	14	32	XII	11	31	XII	2	25
7		6	51		14	35		11	17		2	8
8		7	17		14	37		10	2		1	51
9		7	42		14	39		10	46		1	34
10		8	6		14	40		10	31		1	17
11	XII	8	30	XII	14	40	XII	10	14	XII	1	1
12		8	53		14	39		9	58		0	44
13		9	16		14	37		9	41		0	29
14		9	38		14	35		9	24		0	13
15		9	59		14	31		9	7	XI	59	58
16	XII	10	20	XII	14	27	XII	8	49	XI	59	43
17		10	39		14	23		8	32		59	28
18		10	58		14	17		8	14		59	14
19		11	17		14	11		7	55		59	0
20		11	34		14	5		7	37		58	47
21	XII	11	51	XII	13	57	XII	7	19	XI	58	34
22		12	7		13	49		7	0		58	22
23		12	22		13	41		6	42		58	10
24		12	36		13	32		6	23		57	58
25		12	50		13	22		6	4		57	47
26	XII	13	3	XII	13	12	XII	5	46	XI	57	37
27		13	15		13	1		5	27		57	27
28		13	27		12	50		5	8		57	17
29		13	37					4	50		57	8
30		13	47					4	31		57	0
31		13	56					4	13			

A TABLE ſhewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The third Year after Leap-Year.

Days.	May.			June.			July.			Auguſt.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XI	56	52	XI	57	22	XII	3	20	XII	5	54
2		56	45		57	31		3	31		5	50
3		56	38		57	41		3	42		5	46
4		56	32		57	51		3	53		5	41
5		56	26		58	1		4	4		5	35
6	XI	56	21	XI	58	12	XII	4	14	XII	5	29
7		56	17		58	23		4	24		5	22
8		56	13		58	34		4	34		5	15
9		56	9		58	45		4	43		5	7
10		56	6		58	57		4	52		4	58
11	XI	56	4	XI	59	8	XII	5	0	XII	4	49
12		56	2		59	21		5	8		4	40
13		56	1		59	33		5	15		4	29
14		56	0		59	45		5	22		4	19
15		56	0		59	58		5	28		4	7
16	XI	56	1	XII	0	10	XII	5	34	XII	3	55
17		56	2		0	23		5	39		3	43
18		56	4		0	36		5	44		3	30
19		56	6		0	49		5	48		3	17
20		56	8		1	1		5	52		3	3
21	XI	56	11	XII	1	14	XII	5	55	XII	2	48
22		56	15		1	27		5	58		2	34
23		56	20		1	40		6	0		2	19
24		56	25		1	53		6	2		2	3
25		56	30		2	6		6	3		1	47
26	XI	56	36	XII	2	18	XII	6	3	XII	1	31
27		56	43		2	31		6	3		1	14
28		56	50		2	44		6	2		0	57
29		56	57		2	56		6	1		0	39
30		57	5		3	8		5	59		0	22
31		57	13					5	57		0	4

A TABLE ſhewing what Time it ought to be by the Clock when the Sun's Center is on the Meridian.

The third Year after Leap-Year.

Days.	September.			October.			November.			December.		
	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
1	XI	59	45	XI	49	37	XI	43	47	XI	49	27
2		59	26		49	19		43	47		49	50
3		59	7		49	0		43	47		50	14
4		58	48		48	42		43	47		50	38
5		58	28		48	24		43	49		51	3
6	XI	58	9	XI	48	7	XI	43	52	XI	51	29
7		57	49		47	50		43	55		51	55
8		57	28		47	33		43	59		52	21
9		57	8		47	17		44	4		52	48
10		56	47		47	1		44	10		53	15
11	XI	56	27	XI	46	46	XI	44	17	XI	53	43
12		56	6		46	31		44	25		54	11
13		55	45		46	17		44	33		54	40
14		55	24		46	3		44	43		55	8
15		55	3		45	50		44	53		55	37
16	XI	54	42	XI	45	37	XI	45	4	XI	56	7
17		54	20		45	25		45	16		56	36
18		53	59		45	14		45	29		57	6
19		53	38		45	3		45	42		57	36
20		53	17		44	53		45	57		58	6
21	XI	52	56	XI	44	43	XI	46	12	XI	58	36
22		52	36		44	35		46	28		59	6
23		52	15		44	27		46	45		59	36
24		51	55		44	19		47	3		0	6
25		51	35		44	13		47	21		0	36
26	XI	51	14	XI	44	7	XI	47	40	XII	1	6
27		50	54		44	1		48	0		1	36
28		50	35		43	57		48	21		2	6
29		50	15		43	53		48	42		2	35
30		49	56		43	50		49	4		3	5
31					43	48					3	34

*** OBSERVE by a good Meridian Line, or by a Tranſit Inſtrument, properly fixed, the Moment when the Sun's center is on the Meridian; and ſet the Clock to the time marked in the preceding Table for that Day of the year. Then if the Clock goes true, it will point to the Time ſhewn in the Table every day afterward at the Inſtant when it is Noon by the Sun, which is when his Center is on the Meridian.—Thus, in the firſt Year after Leap-year, on the 20th of October, when it is Noon by the Sun, the true equal Time by the Clock is only 44 minutes 49 ſeconds paſt XI; and on the laſt day of December (in that Year) it ſhould be 3 minutes 47 ſeconds paſt XII by the Clock when the Sun's center is on the Meridian.

The following Table was made from the preceding one, and is of the common form of a Table of the Equation of Time, ſhewing how much a Clock regulated to keep mean or equal time is before or behind the Apparent or Solar time every Day of the Year.

A

TABLE

OF THE

EQUATION OF TIME,

SHEWING

How much a CLOCK ſhould be FASTER or SLOWER than the SUN, at the Noon of every Day in the Year, both in LEAP-YEARS and COMMON YEARS.

[*The Aſteriſks in the Tables ſhew where the Equation changes to Slow or Faſt.*]

A TABLE of the Equation of Time, ſhewing how much a Clock ſhould be faſter or ſlower than the Sun, every Day of the Year, at Noon.

The Biſſextile, or Leap-Year.

Days.	Jan.		Feb.		March.		April.		May.		June.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	4	2	14	3	12	30	3	42	3	12	2	30
2	4	30	14	10	12	17	3	24	3	19	2	20
3	4	58 Clock	14	16 Clock	12	4 Clock	3	6 Clock	3	26 Clock	2	11 Clock
4	5	25	14	22	11	50	2	48	3	32	2	1
5	5	52	14	27	11	35	2	30	3	37	1	51
6	6	19	14	31	11	21	2	13	3	42	1	40
7	6	45	14	34	11	6	1	55	3	46	1	29
8	7	10 faſter.	14	37 faſter.	10	50 faſter.	1	38 faſter.	3	50 ſlower.	1	18 ſlower.
9	7	35	14	38	10	34	1	21	3	53	1	6
10	8	00	14	39	10	18	1	4	3	55	0	54
11	8	24	14	39	10	2	0	48	3	57	0	42
12	8	47	14	38	9	45	0	32	3	59	0	30
13	9	10	14	37	9	28	0	17	4	00	0	18
14	9	32	14	35	9	11	0	1	4	00	0	5
15	9	53	14	32	8	54	0*	13	3	59	0*	8
16	10	14	14	28	8	36	0	28	3	58	0	21
17	10	34	14	24	8	18	0	42	3	56	0	33
18	10	53	14	19	8	00	0	56 Clock	3	54	0	46 Clock
19	11	12	14	13	7	42	1	9	3	51	0	59
20	11	30	14	7	7	24	1	22	3	48	1	13
21	11	47	14	00	7	6	1	34	3	44	1	26
22	12	3	13	52	6	47	1	46	3	40	1	39
23	12	19	13	44	6	29	1	57 ſlower.	3	35	1	52 faſter.
24	12	34	13	35	6	10	2	8	3	30	2	5
25	12	48	13	26	5	52	2	19	3	24	2	17
26	13	1	13	16	5	33	2	29	3	17	2	30
27	13	13	13	5	5	15	2	39	3	10	2	42
28	13	25	12	54	4	56	2	48	3	3	2	54
29	13	36	12	42	4	37	2	56	2	55	3	6
30	13	46			4	19	3	4	2	47	3	18
31	13	55			4	00			2	39		

A TABLE of the Equation of Time, ſhewing how much a Clock ſhould be faſter or ſlower than the Sun, every Day of the Year, at Noon.

The Biſſextile, or Leap Year.

Days.	July. M.	July. S.	Auguſt. M.	Auguſt. S.	Sept. M.	Sept. S.	October. M.	October. S.	Nov. M.	Nov. S.	Dec. M.	Dec. S.
1	3	29	5	51	0	30	10	38	16	15	10	17
2	3	40	5	47	0	49	10	57	16	15	9	53
3	3 Clock	51	5 Clock	42	1 Clock	8	11 Clock	15	16 Clock	15	9 Clock	29
4	4	1	5	36	1	28	11	33	16	13	9	4
5	4	12	5	30	1	48	11	51	16	11	8	39
6	4	22	5	23	2	8	12	8	16	7	8	13
7	4	31	5	16	2	28	12	24	16	3	7	47
8	4 faſter.	40	5 faſter.	8	2 ſlower.	48	12 ſlower.	41	15 ſlower.	58	7 ſlower.	20
9	4	49	5	00	3	9	12	56	15	52	6	52
10	4	57	4	51	3	30	13	12	15	46	6	25
11	5	5	4	41	3	50	13	27	15	38	5	57
12	5	13	4	31	4	11	13	41	15	29	5	28
13	5	20	4	21	4	32	13	55	15	20	4	59
14	5	26	4	10	4	53	14	8	15	10	4	30
15	5	32	3	58	5	14	14	20	14	59	4	00
16	5	38	3	46	5	35	14	32	14	47	3	31
17	5	43	3	33	5	56	14	44	14	34	3	1
18	5	48	3	20	6	16	14	54	14	21	2	31
19	5	52	3	6	6	37	15	5	14	7	2	1
20	5	56	2	52	6	58	15	14	13	52	1	31
21	5	59	2	38	7	19	15	23	13	36	1	1
22	6	1	2	23	7	40	15	31	13	19	0	31
23	6	3	2	7	8	00	15	39	13	2	0	1
24	6	4	1	51	8	20	15	46	12	44	0	* 29
25	6	4	1	35	8	41	15	52	12	25	0	59
26	6	4	1	18	9	1	15	58	12	5	1	29
27	6	4	1	1	9	21	16	3	11	45	1	58
28	6	2	0	44	9	41	16	7	11	24	2 faſter.	27
29	6	00	0	26	10	00	16	10	11	2	2	56
30	5	58	0	8	10	19	16	12	10	40	3	25
31	5	55	0	* 11			16	14			3	54

A TABLE of the Equation of Time, ſhewing how much a Clock ſhould be faſter or ſlower than the Sun, every Day of the Year, at Noon.

The firſt Year after Leap-Year.

Days.	Jan. M.		Jan. S.	Feb. M.		Feb. S.	March. M.		March. S.	April. M.		April. S.	May. M.		May. S.	June. M.		June. S.
1	4		23	14		9	12		33	3		47	3		11	2		33
2	4		51	14		16	12		20	3		29	3		18	2		24
3	5	Clock	19	14	Clock	21	12	Clock	7	3	Clock	10	3	Clock	25	2	Clock	14
4	5		46	14		26	11		54	2		52	3		31	2		4
5	6		13	14		31	11		40	2		35	3		36	1		54
6	6		39	14		34	11		25	2		17	3		41	1		43
7	7		4	14		37	11		10	2		00	3		45	1		33
8	7	faſter.	30	14	faſter.	39	10	faſter.	55	1	faſter.	43	3	ſlower.	49	1	ſlower.	22
9	7		54	14		40	10		39	1		26	3		53	1		10
10	8		18	14		40	10		23	1		9	3		55	0		58
11	8		41	14		39	10		7	0		52	3		57	0		46
12	9		4	14		38	9		50	0		36	3		59	0		34
13	9		26	14		36	9		33	0		20	4		00	0		22
14	9		48	14		33	9		16	0		5	4		00	0		10
15	10		9	14		29	8		58	0	*	10	4		00	0	*	3
16	10		29	14		25	8		41	0		25	3		59	0		16
17	10		48	14		20	8		23	0		39	3		58	0		29
18	11		7	14		15	8		5	0	Clock	53	3		56	0	Clock	42
19	11		25	14		9	7		47	1		6	3		53	0		55
20	11		42	14		2	7		29	1		19	3		50	1		8
21	11		59	13		54	7		10	1		32	3		47	1		21
22	12		15	13		46	6		52	1		44	3		42	1		34
23	12		30	13		37	6		33	1	ſlower.	56	3		38	1	faſter.	47
24	12		44	13		28	6		15	2		7	3		32	2		00
25	12		58	13		18	5		56	2		17	3		26	2		13
26	13		10	13		8	5		38	2		28	3		20	2		25
27	13		22	12		57	5		19	2		37	3		13	2		38
28	13		33	12		45	5		00	2		46	3		6	2		50
29	13		43				4		42	2		55	2		58	3		2
30	13		52				4		23	3		3	2		50	3		14
31	14		1				4		5				2		42			

A TABLE of the Equation of Time, ſhewing how much a Clock ſhould be faſter or ſlower than the Sun, every Day of the Year, at Noon.

The firſt Year after Leap-Year.

Days.	July.		Auguſt.		Sept.		October.		Nov.		Dec.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
	Clock		Clock		Clock		Clock		Clock		Clock	
1	3	26	5	52	0	24	10	32	16	14	10	22
2	3	37	5	48	0	43	10	51	16	14	9	59
3	3	48	5	43	1	2	11	9	16	13	9	35
4	3	58	5	38	1	22	11	27	16	12	9	10
5	4	9	5	32	1	42	11	45	16	10	8	45
	faſter.		faſter.		ſlower.		ſlower.		ſlower.		ſlower.	
6	4	19	5	25	2	2	12	2	16	7	8	19
7	4	28	5	18	2	22	12	19	16	3	7	53
8	4	37	5	10	2	42	12	35	15	59	7	26
9	4	46	5	2	3	3	12	51	15	53	6	59
10	4	55	4	53	3	23	13	7	15	47	6	31
11	5	3	4	44	3	44	13	22	15	39	6	3
12	5	10	4	34	4	5	13	36	15	31	5	35
13	5	17	4	24	4	26	13	50	15	22	5	6
14	5	24	4	13	4	47	14	3	15	12	4	37
15	5	30	4	1	5	8	14	16	15	1	4	8
16	5	36	3	49	5	29	14	28	14	50	3	38
17	5	41	3	37	5	50	14	40	14	37	3	9
18	5	46	3	24	6	10	14	51	14	24	2	39
19	5	50	3	10	6	31	15	1	14	10	2	9
20	5	54	2	56	6	52	15	11	13	55	1	39
21	5	57	2	42	7	13	15	20	13	39	1	9
22	6	00	2	27	7	33	15	29	13	23	0	38
23	6	2	2	12	7	54	15	36	13	6	0	8
24	6	3	1	56	8	14	15	43	12	48	0	*22
25	6	4	1	40	8	35	15	50	12	29	0	52
											faſter.	
26	6	4	1	23	8	55	15	55	12	9	1	22
27	6	4	1	6	9	15	16	00	11	49	1	51
28	6	3	0	49	9	34	16	4	11	28	2	20
29	6	1	0	31	9	54	16	8	11	7	2	50
30	5	59	0	13	10	13	16	11	10	45	3	19
31	5	56	0*	5			16	13			3	47

A TABLE of the Equation of Time, ſhewing how much a Clock ſhould be faſter or ſlower than the Sun, every Day of the Year, at Noon.

The ſecond Year after Leap-Year.

Days.	Jan.		Feb.		March.		April.		May.		June.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	4	15	14	6	12	35	3	50	3	10	2	36
2	4	43	14	13	12	23	3	32	3	17	2	27
3	5 Clock	11	14 Clock	19	12 Clock	9	3 Clock	14	3 Clock	24	2 Clock	17
4	5	38	14	24	11	56	2	56	3	30	2	8
5	6	5	14	28	11	42	2	38	3	36	1	57
6	6	31	14	32	11	27	2	20	3	41	1	47
7	6	57	14	35	11	13	2	3	3	45	1	36
8	7 faſter.	22	14 faſter.	37	10 faſter.	58	1 faſter.	46	3 ſlower.	49	1 ſlower.	25
9	7	47	14	39	10	42	1	29	3	52	1	13
10	8	11	14	39	10	26	1	12	3	55	1	1
11	8	35	14	39	10	10	0	56	3	57	0	49
12	8	58	14	38	9	54	0	40	3	59	0	37
13	9	21	14	36	9	37	0	24	4	00	0	24
14	9	43	14	34	9	20	0	9	4	00	0	12
15	10	4	14	31	9	3	0 *	6	4	00	0 *	1
16	10	24	14	27	8	45	0	21	3	59	0	14
17	10	44	14	22	8	27	0	35	3	58	0	27
18	11	3	14	17	8	10	0 Clock	49	3	56	0 Clock	40
19	11	22	14	11	7	52	1	2	3	53	0	53
20	11	39	14	4	7	34	1	15	3	50	1	6
21	11	56	13	57	7	15	1	28	3	47	1	19
22	12	12	13	49	6	57	1	40	3	43	1	32
23	12	27	13	40	6	38	1 ſlower.	52	3	38	1 faſter.	44
24	12	41	13	31	6	20	2	4	3	33	1	57
25	12	55	13	21	6	1	2	15	3	28	2	10
26	13	7	13	10	5	42	2	25	3	22	2	22
27	13	19	12	59	5	23	2	35	3	15	2	34
28	13	30	12	47	5	5	2	45	3	8	2	46
29	13	40			4	46	2	54	3	1	2	58
30	13	50			4	27	3	2	2	53	3	10
31	13	58			4	9			2	45		

A TABLE of the Equation of Time, ſhewing how much a Clock ſhould be faſter or ſlower than the Sun, every Day of the Year, at Noon.

The ſecond Year after Leap-Year.

Days.	July.		Auguſt.		Sept.		October.		Nov.		Dec.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
	Clock faſter.		Clock faſter.		Clock ſlower.		Clock ſlower.		Clock ſlower.		Clock ſlower.	
1	3	22	5	53	0	20	10	28	16	14	10	28
2	3	33	5	49	0	39	20	46	16	14	10	4
3	3	44	5	44	0	58	11	5	16	14	9	40
4	3	55	5	39	1	17	11	23	16	12	9	16
5	4	5	5	33	1	37	11	40	16	10	8	51
6	4	16	5	27	1	56	11	57	16	7	8	25
7	4	26	5	20	2	16	12	14	16	3	7	59
8	4	35	5	13	2	37	12	30	15	59	7	32
9	4	44	5	5	2	57	12	46	15	53	7	5
10	4	53	4	56	3	17	13	2	15	47	6	37
11	5	1	4	47	3	38	13	17	15	40	6	9
12	5	9	4	37	3	59	13	31	15	32	5	41
13	5	17	4	27	4	19	13	45	15	23	5	12
14	5	24	4	17	4	40	13	59	15	13	4	43
15	5	30	4	5	5	1	14	12	15	3	4	14
16	5	36	3	53	5	22	14	24	14	52	3	45
17	5	41	3	41	5	43	14	36	14	40	3	15
18	5	46	3	28	6	4	14	47	14	27	2	46
19	5	50	3	15	6	25	14	58	14	13	2	16
20	5	54	3	1	6	46	15	8	13	58	1	46
21	5	57	2	46	7	7	15	18	13	43	1	16
22	6	00	2	31	7	28	15	26	13	27	0	46
23	6	2	2	16	7	49	15	34	13	10	0	16
24	6	3	2	00	8	9	15	42	12	52	0*	14
25	6	4	1	44	8	30	15	49	12	34	0	44
26	6	4	1	27	8	50	15	54	12	15	1	13
27	6	3	1	10	9	10	15	59	11	55	1	43 (faſter.)
28	6	2	0	53	9	30	16	4	11	34	2	12
29	6	1	0	35	9	49	16	8	11	13	2	42
30	5	59	0	17	10	9	16	11	10	51	3	11
31	5	56	0*	1			16	12			3	40

A TABLE of the Equation of Time, ſhewing how much a Clock ſhould be faſter or ſlower than the Sun, every Day of the Year, at Noon.

The third Year after Leap-Year.

Days.	Jan.		Feb.		March.		April.		May.		June.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	4	8	14	4	12	38	3	55	3	8	2	38
2	4	36	14	11	12	25	3	36	3	15	2	29
3	5	Clock 4	14	Clock 17	11	Clock 12	3	Clock 18	3	Clock 22	2	Clock 19
4	5	32	14	23	11	59	3	00	3	28	2	9
5	5	59	14	28	11	45	2	43	3	34	1	59
6	6	25	14	32	11	31	2	25	3	39	1	48
7	6	51	14	35	11	17	2	8	3	43	1	37
8	7	faſter. 17	14	faſter. 37	11	faſter. 2	1	faſter. 51	3	ſlower. 47	1	ſlower. 26
9	7	42	14	39	10	46	1	34	3	51	1	15
10	8	6	14	40	10	30	1	17	3	54	1	3
11	8	30	14	40	10	14	1	1	3	56	0	51
12	8	53	14	39	9	58	0	45	3	58	0	39
13	9	16	14	37	9	41	0	29	3	59	0	27
14	9	38	14	35	9	24	0	13	4	00	0	15
15	9	59	14	31	9	7	0*	2	4	00	0	2
16	10	20	14	27	8	49	0	17	3	59	0*	10
17	10	39	14	23	8	32	0	32	3	58	0	23
18	10	58	14	17	8	14	0	Clock 46	3	56	0	Clock 36
19	11	16	14	11	7	56	1	00	3	54	0	49
20	11	34	14	5	7	37	1	13	3	52	1	2
21	11	51	13	57	7	19	1	26	3	49	1	14
22	12	7	13	49	7	00	1	38	3	45	1	27
23	12	22	13	41	6	42	1	ſlower. 50	3	40	1	faſter. 40
24	12	36	13	32	6	23	2	2	3	35	1	53
25	12	50	13	22	6	4	2	13	3	30	2	6
26	13	3	13	12	5	46	2	23	3	24	2	18
27	13	15	13	1	5	27	2	33	3	17	2	31
28	13	26	12	50	5	8	2	43	3	10	2	43
29	13	37			4	50	2	52	3	3	2	56
30	13	47			4	31	3	00	2	55	3	8
31	13	56			4	13			2	47		

A TABLE of the Equation of Time, ſhewing how much a Clock ſhould be faſter or ſlower than the Sun, every Day of the Year, at Noon.

The third Year after Leap-Year.

Days.	July. M.	July. S.	Auguſt. M.	Auguſt. S.	Sept. M.	Sept. S.	October. M.	October. S.	Nov. M.	Nov. S.	Dec. M.	Dec. S.
1	3	20	5	54	0 *	15	10	23	16	13	10	33
2	3	31	5	50	0	34	10	42	16	14	10	10
3	3 Clock	42	5 Clock	46	0 Clock	53	11 Clock	00	16 Clock	14	9 Clock	46
4	3	53	5	41	1	12	11	18	16	13	9	22
5	4	4	5	35	1	32	11	36	16	11	8	57
6	4	14	5	29	1	51	11	53	16	8	8	31
7	4	24	5	22	2	11	12	10	16	5	8	5
8	4 faſter.	34	5 faſter.	15	2 ſlower.	32	12 ſlower.	27	16 ſlower.	1	7 ſlower.	39
9	4	43	5	7	2	52	12	43	15	55	7	12
10	4	52	4	58	3	13	12	59	15	49	6	45
11	5	00	4	49	3	34	13	14	15	43	6	17
12	5	8	4	40	3	54	13	29	15	35	5	49
13	5	15	4	29	4	15	13	43	15	27	5	20
14	5	22	4	18	4	36	13	57	15	17	4	52
15	5	28	4	7	4	57	14	10	15	7	4	23
16	5	34	3	55	5	18	14	23	14	56	3	54
17	5	39	3	43	5	40	14	35	14	44	3	24
18	5	44	3	30	6	1	14	46	14	31	2	54
19	5	48	3	17	6	22	14	57	14	18	2	24
20	5	52	3	3	6	43	15	7	14	3	1	54
21	5	55	2	48	7	4	15	17	13	48	1	24
22	5	58	2	34	7	24	15	25	13	32	0	54
23	6	00	2	19	7	45	15	33	13	15	0	24
24	6	2	2	3	8	5	15	41	12	57	0 *	6
25	6	3	1	47	8	25	15	48	12	39	0	36
26	6	3	1	31	8	46	15	53	12	20	1	6
27	6	3	1	14	9	6	15	59	12	00	1	36
28	6	2	0	57	9	25	16	3	11	39	2 faſter.	6
29	6	1	0	39	9	45	16	7	11	18	2	35
30	5	59	0	22	10	4	16	10	10	56	3	5
31	5	57	0	4			16	12			3	34

A concise EQUATION TABLE, adapted to the Second Year after Leap-Year, and will be within a Minute of the Truth for every Year; shewing to the nearest full Minute, how much a Clock should be faster or slower than the Sun. *By* Mr. SMEATON.

Months.	Days.	Equ. in Minutes.		Months.	Days.	Equ. in Minutes.		Months.	Days.	Equ. in Minutes.		Months.	Days.	Equ. in Minutes.	
Jan.	1	4	Clock faster than the Sun.	Apr.	1	4	Clock faster.	Aug.	10	5	Clock faster.	Oct.	27	16	
	3	5			4	3			15	4		Nov.	8	16	
	5	6			7	2			20	3			15	15	Clock slower than the Sun.
	7	7			11	1			24	2			20	14	
	10	8			15	0			28	1			24	13	
	12	9			*				31	0			27	12	
	15	10			19	1	Clock slower.		*				30	11	
	18	11			24	2		Sept.	3	1	Clock slower than the Sun,	Dec.	2	10	
	21	12			30	3			6	2			5	9	
	25	13		May	14	4			9	3			7	8	
	31	14			29	3			12	4			9	7	
Feb.	6	15		June	5	2			15	5			11	6	
	21	14			10	1			18	6			13	5	
	27	13			15	0			21	7			15	4	
Mar.	4	12			*				24	8			18	3	
	8	11			20	1	Clock faster.		27	9			20	2	
	12	10			24	2			30	10			22	1	
	15	9			29	3		Oct.	3	11			24	0	
	19	8		July	4	4			6	12			*		
	22	7			11	5			10	13			26	1	Faster.
	25	6			26	6			14	14			28	2	
	28	5							19	15			30	3	

This Table is near enough for regulating common Clocks and Watches. It may be easily copied by the Pen, and being doubled, may be put into a Pocket-book.

CHAP.

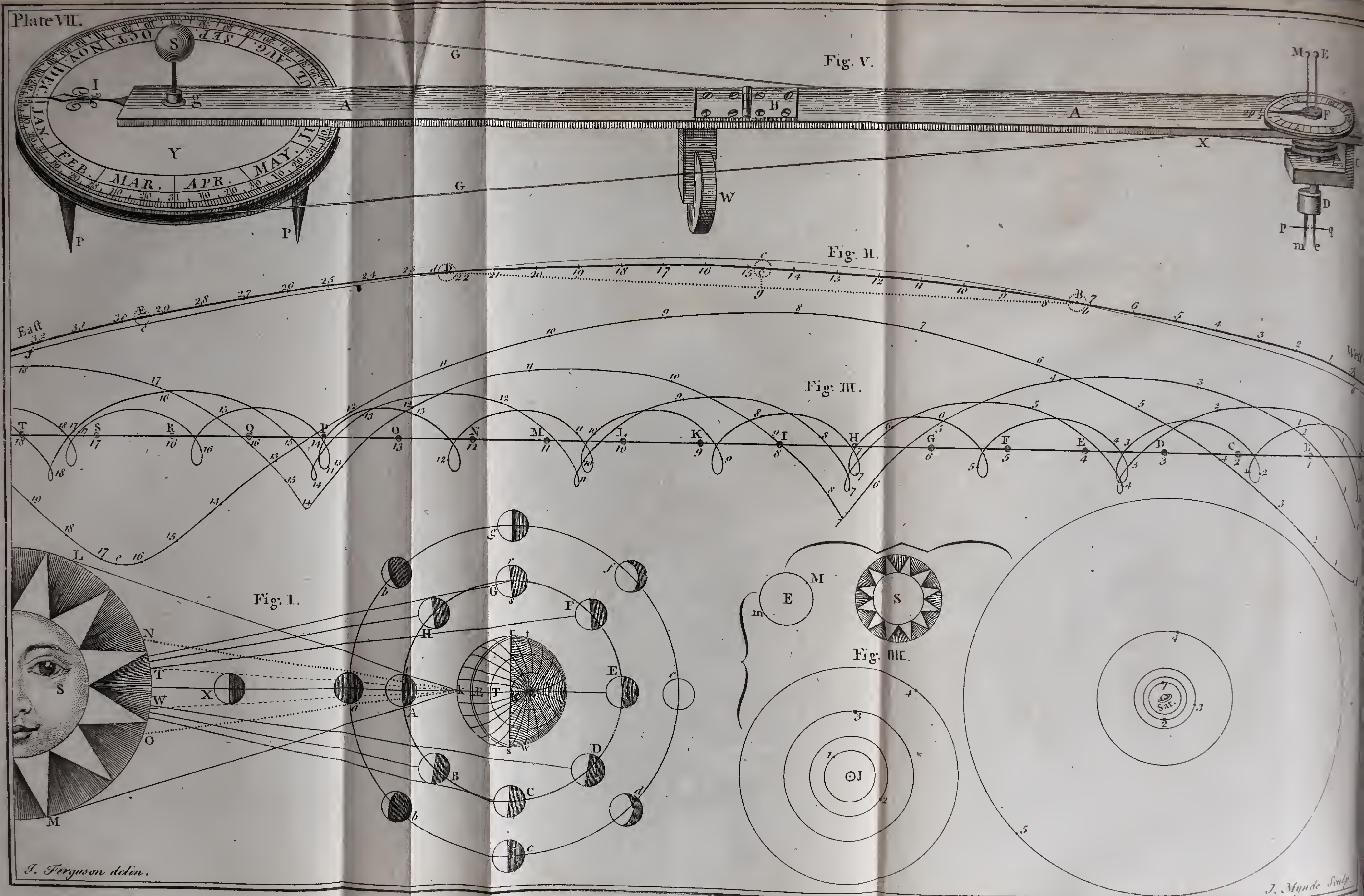


Plate VII.
Fig. V.
Fig. II.
East
West
Fig. III.
Fig. I.
Fig. IIII.
J. Ferguson delin.
J. Mynde Sculp.

CHAP. XV.

The Moon's Surface mountainous: Her Phases described: Her Path, and the Paths of Jupiter's Moons delineated: The Proportions of the Diameters of their Orbits, and those of Saturn's Moons, to each other; and to the Diameter of the Sun.

252. BY looking at the Moon with an ordinary telescope, we perceive that her surface is diversified with long tracts of prodigious high mountains and deep cavities. Some of her mountains, by comparing their height with her diameter (which is 2180 miles), are found to be three times higher than the highest hills on our Earth. This ruggedness of the Moon's surface is of great use to us, by reflecting the Sun's light to all sides: for if the Moon were smooth and polished like a looking-glass, or covered with water, she could never distribute the Sun's light all round; only in some positions she would shew us his image, no bigger than a point, but with such a lustre as would be hurtful to our eyes. PLATE VII. The Moon's surface mountainous.

253. The Moon's surface being so uneven, many have wondered why her edge appears not jagged as well as the curve bounding the light and dark parts. But if we consider, that what we call the edge of the Moon's Disc is not a single line set round with mountains, in which case it would appear irregularly indented, but a large zone having many mountains lying behind one another from the observer's eye, we shall find that the mountains in some rows will be opposite to the vales in others, and fill up the inequalities so as to make her appear quite round; just as when one looks at an orange, although its roughness be very discernible on the side next the eye, especially if the Sun or a Candle shines obliquely on that side, yet the line terminating Why no hills appear on her edge.

PLATE VII. terminating the viſible part ſtill appears ſmooth and even.

The Moon has no twilight.

254. As the Sun can only enlighten that half of the Earth which is at any moment turned toward him, and being withdrawn from the oppoſite half, leaves it in darkneſs; ſo he likewiſe doth to the Moon: only with this difference, that the Earth, being ſurrounded by an Atmoſphere, and the Moon, as far as we know, having none, we have twilight after the Sun ſets; but the Lunar inhabitants have an immediate tranſition from the brighteſt Sun-ſhine to the blackeſt darkneſs, § 177. For, let *t r k s w* be the earth, and *A*, *B*, *C*, *D*, *E*, *F*, *G*, *H* the Moon in eight different parts of her Orbit. As the Earth turns round its Axis, from weſt to eaſt, when any place comes to *t* the twilight begins there, and when it revolves from thence to *r* the Sun *S* riſes; when the place comes to *s* the Sun ſets, and when it comes to *w* the twilight ends. But as the Moon turns round her Axis, which is only once a month, the moment that any point of her ſurface comes to *r* (ſee the Moon at *G*) the Sun riſes there without any previous warning by twilight; and when the ſame point comes to *s* the Sun ſets, and that point goes into darkneſs as black as at midnight.

Fig. I.

The Moon's Phaſes.

255. The Moon being an opaque ſpherical body (for her hills take off no more from her roundneſs than the inequalities on the ſurface of an orange take off from its roundneſs) we can only ſee that part of the enlightened half of her which is toward the Earth. And therefore when the Moon is at *A*, in conjunction with the Sun *S*, her dark half is toward the Earth, and ſhe diſappears, as at *a*, there being no light on that half to render it viſible. When ſhe comes to her firſt Octant at *B*, or has gone an eighth part of her Orbit from her Conjunction, a quarter of her enlightened ſide is ſeen toward the Earth, and ſhe appears horned, as at *b*. When ſhe has gone a quarter of her Orbit from

from between the Earth and Sun to *C*, ſhe ſhews us one half of her enlightened ſide, as at *c*, and we ſay, ſhe is a quarter old. At *D* ſhe is in her ſecond Octant, and by ſhewing us more of her enlightened ſide ſhe appears gibbous, as at *d*. At *E* her whole enlightened ſide is toward the Earth, and therefore ſhe appears round, as at *e*, when we ſay it is Full Moon. In her third Octant at *F*, part of her dark ſide being toward the Earth, ſhe again appears gibbous, and is on the decreaſe, as at *f*. At *G* we ſee juſt one half of her enlightened ſide, and ſhe appears half decreaſed, or in her third Quarter, as at *g*. At *H* we only ſee a quarter of her enlightened ſide, being in her fourth Octant, where ſhe appears horned, as at *h*. And at *A*, having completed her courſe from the Sun to the Sun again, ſhe diſappears; and we ſay, it is New Moon. Thus, in going from *A* to *E*, the Moon ſeems continually to increaſe; and in going from *E* to *A*, to decreaſe in the ſame proportion; having like Phaſes at equal diſtances from *A* to *E*, but as ſeen from the Sun *S*, ſhe is always Full.

256. The Moon appears not perfectly round when ſhe is Full in the higheſt or loweſt part of her Orbit, becauſe we have not a full view of her enlightened ſide at that time. When Full in the higheſt part of her Orbit, a ſmall deficiency appears on her lower edge; and the contrary when Full in the loweſt part of her Orbit. The Moon's Diſc not always quite round when full.

257. It is plain by the figure, that when the Moon changes to the Earth, the Earth appears Full to the Moon; and *vice verſa*. For when the Moon is at *A*, *New* to the Earth, the whole enlightened ſide of the Earth is toward the Moon; and when the Moon is at *E*, *Full* to the Earth, its dark ſide is toward her. Hence a *New Moon* anſwers to a *Full Earth*, and a *Full Moon* to a *New Earth*. The *Quarters* are alſo reverſed to each other. The Phaſes of the Earth and Moon contrary.

258. Between the third Quarter and Change, the Moon is frequently viſible in the forenoon, even when An Agreeable Phenomenon.

when the Sun ſhines; and then ſhe affords us an opportunity of ſeeing a very agreeable appearance wherever we find a globular ſtone above the level of the eye, as ſuppoſe on the top of a gate. For if the Sun ſhines on the ſtone, and we place ourſelves ſo as the upper part of the ſtone may juſt ſeem to touch the point of the Moon's lowermoſt horn, we ſhall then ſee the enlightened part of the ſtone exactly of the ſame ſhape with the Moon; horned as ſhe is, and inclined the ſame way to the Horizon. The reaſon is plain; for the Sun enlightens the ſtone the ſame way as he does the Moon: and both being Globes, when we put ourſelves into the above ſituation, the Moon and ſtone have the ſame poſition to our eyes; and therefore we muſt ſee as much of the illuminated part of the one as of the other.

The Nonageſimal Degree, what.

259. The poſition of the Moon's Cuſps, or a right line touching the points of her horns, is very differently inclined to the Horizon at different hours of the ſame days of her age. Sometimes ſhe ſtands, as it were, upright on her lower horn, and then ſuch a line is perpendicular to the Horizon; when this happens, ſhe is in what the Aſtronomers call *the Nonageſimal Degree*; which is the higheſt point of the Ecliptic above the Horizon at that time, and is 90 degrees from both ſides of the Horizon where it is then cut by the Ecliptic. But this never happens when the Moon is on the Meridian, except when ſhe is at the very beginning of Cancer or Capricorn.

How the inclination of the Ecliptic may be found by the poſition of the Moon's horns.

260. The inclination of that part of the Ecliptic to the Horizon in which the Moon is at any time when horned, may be known by the poſition of her horns; for a right line touching their points is perpendicular to the Ecliptic. And as the angle which the Moon's Orbit makes with the Ecliptic can never raiſe her above, nor depreſs her below the Ecliptic, more than two minutes of a degree, as ſeen from the Sun; it can have no

ſenſible

ſenſible effect upon the poſition of her horns. Therefore, if a Quadrant be held up, ſo as one of its edges may ſeem to touch the Moon's horns, the graduated ſide being kept toward the eye, and as far from the eye as it can be conveniently held, the Arc between the Plumb-line and that edge of the Quadrant which ſeems to touch the Moon's horns will ſhew the inclination of that part of the Ecliptic to the Horizon. And the arc between the other edge of the Quadrant and Plumb-line will ſhew the inclination of a line, touching the Moon's horns, to the Horizon: PLATE VII.

261. The Moon generally appears as large as the Sun; for the Angle *v k A*, under which the Moon is ſeen from the Earth, is the ſame with the Angle *LkM*, under which the Sun is ſeen from it. And therefore the Moon may hide the Sun's whole Diſc from us, as ſhe ſometimes does in ſolar Eclipſes. The reaſon why ſhe does not eclipſe the Sun at every Change, ſhall be explained afterward. If the Moon were farther from the Earth, as at *a*, ſhe would never hide the whole of the Sun from us; for then ſhe would appear under the Angle *NkO*, eclipſing only that part of the Sun which lies between *N* and *O*: were ſhe ſtill further from the Earth, as at *X*, ſhe would appear under the ſmall angle *TkW*, like a ſpot on the Sun, hiding only the part *TW* from our ſight. Fig. I. Why the Moon appears as big as the Sun.

262. That the Moon turns round her Axis in the time that ſhe goes round her Orbit, is quite demonſtrable; for a ſpectator at reſt, without the periphery of the Moon's Orbit, would ſee all her ſides turned regularly toward him in that time. She turns round her Axis from any Star to the ſame Star again in 27 days 8 hours; from the Sun to the Sun again in 29½ days: the former is the length of her ſydereal day, and the latter the length of her ſolar day. A body moving round the Sun would have a ſolar day in every revolution without turning on its Axis; the ſame as if it A proof of the Moon's turning round her Axis.

had kept all the while at reſt, and the Sun moved round it: but without turning round its Axis it could never have one ſydereal day, becauſe it would always keep the ſame ſide toward any given Star.

Her periodical and ſynodical Revolution.

263. If the Earth had no annual motion, the Moon would go round it ſo as to complete a Lunation, a ſydereal, and a ſolar day, all in the ſame time. But becauſe the Earth goes forward in its Orbit while the Moon goes round the Earth in her Orbit, the Moon muſt go as much more than round her Orbit from Change to Change in completing a ſolar day, as the Earth has gone forward in its Orbit during that time, *i. e.* almoſt a twelfth part of a Circle.

Familiarly repreſented.

264. The Moon's periodical and ſynodical revolution may be familiarly repreſented by the motions of the hour and minute-hands of a watch round its dial-plate, which is divided into 12 equal parts or hours, as the Ecliptic is divided into 12 Signs, and the year into 12 months. Let us ſuppoſe theſe 12 hours to be 12 Signs, the hour-hand the Sun, and the minute-hand the Moon; then the former will go round once in a year, and the latter once in a month: but the Moon, or minute-hand, muſt go more than round from any point of the Circle where it was laſt conjoined with

A Table ſhewing the times that the hour and minute-hands of a watch are in conjunction.

Conj.	H.	M.	S.	‴	⁗	vpts.
1	I	5	27	16	21	$49\frac{1}{11}$
2	II	10	54	32	43	$38\frac{2}{11}$
3	III	16	21	49	5	$27\frac{3}{11}$
4	IIII	21	49	5	27	$16\frac{4}{11}$
5	V	27	10	21	49	$5\frac{5}{11}$
6	VI	32	43	38	10	$54\frac{6}{11}$
7	VII	38	10	54	32	$43\frac{7}{11}$
8	VIII	43	38	10	54	$32\frac{8}{11}$
9	IX	49	5	27	16	$21\frac{9}{11}$
10	X	54	32	43	38	$10\frac{10}{11}$
11	XII	0	0	0	0	0

the

the Sun, or hour-hand, to overtake it again: for the hour-hand, being in motion, can never be overtaken by the minute-hand at that point from which they ſtarted at their laſt conjunction. The firſt column of the preceding Table ſhews the number of conjunctions which the hour and minute-hand make while the hour-hand goes once round the dial-plate; and the other columns ſhew the times when the two hands meet at each conjunction. Thus, ſuppoſe the two hands to be in conjunction at XII, as they always are; then, at the firſt following conjunction it is 5 minutes 27 ſeconds 16 thirds 21 fourths $49\frac{1}{11}$ fifths paſt I, where they meet: at the ſecond conjunction it is 10 minutes 54 ſeconds 32 thirds 43 fourths $38\frac{2}{11}$ fifths paſt II; and ſo on. This, though an eaſy illuſtration of the motions of the Sun and Moon, is not preciſe as to the times of their conjunctions; becauſe, while the Sun goes round the Ecliptic, the Moon makes $12\frac{1}{3}$ conjunctions with him; but the minute-hand of a watch or clock makes only 11 conjunctions with the hour-hand in one period round the dial-plate. But if, inſtead of the common wheel-work at the back of the dial-plate, the Axis of the minute-hand had a pinion of 6 leaves turning a wheel of 74, and this laſt turning the hour-hand, in every revolution it makes round the dial plate, the minute-hand would make $12\frac{1}{3}$ conjunctions with it; and ſo would be a pretty device for ſhewing the motions of the Sun and Moon; eſpecially, as the ſloweſt moving hand might have a little Sun fixed on its point, and the quickeſt a little Moon.

The Moon's motion through open ſpace deſcribed.

265. If the Earth had no annual motion, the Moon's motion round the Earth, and her track in open ſpace, would be always the ſame*. But

* In this place, we may conſider the Orbits of all the Satellites as circular, with reſpect to their primary Planets; becauſe the excentricities of their Orbits are too ſmall to effect the Phenomena here deſcribed.

as

PLATE VII. as the Earth and Moon move round the Sun, the Moon's real path in the Heavens is very different from her viſible path round the Earth: the latter being in a progreſſive Circle, and the former in a curve of different degrees of concavity, which would always be the ſame in the ſame parts of the Heavens, if the Moon performed a compleat number of Lunations in a year without any fraction.

An idea of the Earth's path, and the Moon's.

266. Let a nail in the end of the axle of a chariot-wheel repreſent the Earth, and a pin in the nave the Moon; if the body of the chariot be propped up ſo as to keep that wheel from touching the ground, and the wheel be then turned round by hand, the pin will deſcribe a Circle both round the nail, and in the ſpace it moves through. But if the props be taken away, the horſes put to, and the chariot driven over a piece of ground which is circularly convex; the nail in the axle will deſcribe a circular curve, and the pin in the nave will ſtill deſcribe a circle round the progreſſive nail in the axle, but not in the ſpace through which it moves. In this caſe, the curve deſcribed by the nail will reſemble in miniature as much of the Earth's annual path round the Sun, as it deſcribes while the Moon goes as often round the Earth as the pin does round the nail: and the curve deſcribed by the nail will have ſome reſemblance of the Moon's path during ſo many Lunations.

Let us now ſuppoſe that the radius of the circular curve deſcribed by the nail in the axle is to the radius of the circle which the pin in the nave deſcribes round the axle as $337\frac{1}{2}$ to 1; which is the proportion of the radius or ſemi-diameter of the Earth's Orbit to that of the Moon's; or of the Fig. II. circular curve *A* 1 2 3 4 5 6 7 *B*, &c. to the little circle *a*; and then, while the progreſſive nail deſcribes the ſaid curve from *A* to *E*, the pin will go once round the nail with regard to the center of its

its path, and in ſo doing, will deſcribe the curve *abcde*. The former will be a true repreſentation of the Earth's path for one Lunation, and the latter of the Moon's for that time. Here we may ſet aſide the inequalities of the Moon's motion, and alſo the Earth's moving round its common center of gravity and the Moon's: all which, if they were truly copied in this experiment, would not ſenſibly alter the figure of the paths deſcribed by the nail and pin, even though they ſhould rub againſt a plain upright ſurface all the way, and leave their tracts viſible upon it. And if the chariot was driven forward on ſuch a convex piece of ground, ſo as to turn the wheel ſeveral times round, the track of the pin in the nave would ſtill be concave toward the center of the circular curve deſcribed by the pin in the axle; as the Moon's path is always concave to the Sun in the center of the Earth's annual Orbit. PLATE VII.

In this Diagram, the thickeſt curve-line *ABCDE*, with the numeral figures ſet to it, repreſents as much of the Earth's annual Orbit as it deſcribes in 32 days from weſt to eaſt; the little circles at *a*, *b*, *c*, *d*, *e*, ſhew the Moon's Orbit in due proportion to the Earth's; and the ſmalleſt curve *a b c d e f* repreſents the line of the Moon's path in the Heavens for 32 days, accounted from any particular New Moon at *a*. The Machine, Fig. 5th, is for delineating the Moon's path, and ſhall be deſcribed, with the reſt of my Aſtronomical machinery, in the laſt Chapter. The Sun is ſuppoſed to be in the center of the curve *A* 1 2 3 4 5 6 7 *B*, &c. and the ſmall-dotted circles upon it repreſent the Moon's Orbit, of which the radius is in the ſame proportion to the Earth's path in this ſcheme, that the radius of the Moon's Orbit in the Heavens bears to the radius of the Earth's annual path round the Sun: that is, as 240,000, to 81,000,000*, or as 1 to 337½. Proportion of the Moon's Orbit to the Earth's.

* For the true diſtances, ſee p. 108.

PLATE VII. Fig. II.

When the Earth is at *A*, the New Moon is at *a*; and in the seven days that the Earth describes the curve 1 2 3 4 5 6 7, the Moon in accompanying the Earth describes the curve *a b*; and is in her first quarter at *b* when the Earth is at *B*. As the Earth describes the curve *B* 8 9 10 11 12 13 14, the Moon describes the curve *b c*; and is at *c*, opposite to the Sun, when the Earth is at *C*. While the Earth describes the curve *C* 15 16 17 18 19 20 21 22, the Moon describes the curve *c d*; and is in her third Quarter at *d* when the Earth is at *D*. And lastly, while the Earth describes the curve *D* 23 24 25 26 27 28 29, the Moon describes the curve *d e*; and is again in conjunction at *e* with the Sun when the Earth is at *E*, between the 29th and 30th day of the Moon's age, accounted by the numeral Figures from the New Moon at *A*. In describing the curve *a b c d e*, the Moon goes round the progressive Earth as really as if she had kept in the dotted Circle *A*, and the Earth continued immoveable in the center of that Circle.

The Moon's motion always concave toward the Sun.

And thus we see that, although the Moon goes round the Earth in a Circle, with respect to the Earth's center, her real path in the Heavens is not very different in appearance from the Earth's path. To shew that the Moon's path is concave to the Sun, even at the time of Change, it is carried on a little farther into a second Lunation, as to *f*.

How her Motion is alternately retarded and accelerated.

267. The Moon's absolute motion from her Change to her first Quarter, or from *a* to *b*, is so much slower than the Earth's, that she falls 240 thousand miles (equal to the semi-diameter of her Orbit) behind the Earth at her first Quarter in *b*, when the Earth is at *B*; that is, she falls back a space equal to her distance from the Earth. From that time her motion is gradually accelerated to her Opposition or Full at *c*, and then she is come up as far as the Earth, having regained what she lost in her first Quarter from *a* to *b*. From the Full to the last Quarter at *d* her motion continues

5 accelerated,

accelerated, ſo as to be juſt as far before the Earth at *d*, as ſhe was behind it at her firſt Quarter in *b*. But from *d* to *e* her motion is retarded ſo, that ſhe loſes as much with reſpect to the Earth as is equal to her diſtance from it, or to the ſemi-diameter of her Orbit; and by that means ſhe comes to *e*, and is then in conjunction with the Sun as ſeen from the Earth at *E*. Hence we find, that the Moon's abſolute Motion is ſlower than the Earth's from her third Quarter to her firſt; and ſwifter than the Earth's from her firſt Quarter to her third: her path being leſs curved than the Earth's in the former caſe, and more in the latter. Yet it is ſtill bent the ſame way toward the Sun; for if we imagine the concavity of the Earth's Orbit to be meaſured by the length of a perpendicular line *Cg*, let down from the Earth's place upon the ſtraight line *b g d* at the Full of the Moon, and connecting the places of the Earth at the end of the Moon's firſt and third Quarters, that length will be about 640 thouſand miles; and the Moon when New only approaching nearer to the Sun by 240 thouſand miles than the Earth is, the length of the perpendicular let down from her place at that time upon the ſame ſtraight line, and which ſhews the concavity of that part of her path, will be about 400 thouſand miles.

268. The Moon's path being concave to the Sun throughout, demonſtrates that her gravity toward the Sun, at her Conjunction, exceeds her gravity toward the Earth. And if we conſider that the quantity of matter in the Sun is almoſt 230 thouſand times as great as the quantity of matter in the Earth, and that the attraction of each body diminiſhes as the ſquare of the diſtance from it increaſes, we ſhall ſoon find, that the point of equal attraction between the Earth and the Sun, is about 70 thouſand miles nearer the Earth than the Moon is at her Change. It may then appear *A difficulty removed.*

 ſurpriſing

PLATE VII. ſurpriſing that the Moon does not abandon the Earth when ſhe is between it and the Sun, becauſe ſhe is conſiderably more attracted by the Sun than by the Earth at that time. But this difficulty vaniſhes when we conſider, that a common impulſe on any ſyſtem of bodies effects not their relative motions; but that they will continue to attract, impel, or circulate round one another, in the ſame manner as if there was no ſuch impulſe. The Moon is ſo near the Earth, and both of them ſo far from the Sun, that the attractive power of the Sun may be conſidered as equal on both: and therefore the Moon will continue to circulate round the Earth in the ſame manner as if the Sun did not attract them at all. For bodies in the cabin of a ſhip, may move round, or impel one another in the ſame manner when the ſhip is under ſail, as when it is at reſt; becauſe they are all equally affected by the common motion of the ſhip. If by any other cauſe, ſuch as the near approach of a Comet, the Moon's diſtance from the Earth ſhould happen to be ſo much increaſed, that the difference of their gravitating forces toward the Sun ſhould exceed that of the Moon toward the Earth; in that caſe the Moon, when in conjunction, would abandon the Earth, and be either drawn into the Sun, or Comet, or circulate round about it.

269. The curves which Jupiter's Satellites deſcribe, are all of different ſorts from the path deſcribed by our Moon, although the Satellites go round Jupiter as the Moon goes round the Earth. Fig. III. Let *A B C D E*, &c. be as much of Jupiter's Orbit as he deſcribes in 18 days from *A* to *T*; and the curves *a*, *b*, *c*, *d*, will be the paths of his four Moons going round him in his progreſſive motion.

Now let us ſuppoſe all theſe Moons to ſet out from a conjunction with the Sun, as ſeen from Jupiter

PLATE VII. The abſolute Path of Jupiter and his Satellites delineated.

at *A*; then, his firſt or neareſt Moon will be at *a*, his ſecond at *b*, his third at *c*, and his fourth at *d*. At the end of 24 terreſtrial Hours after this conjunction, Jupiter has moved to *B*, his firſt Moon or Satellite has deſcribed the curve *a* 1, his ſecond the curve *b* 1, his third *c* 1, and his fourth *d* 1. The next day, when Jupiter is at *C*, his firſt Satellite has deſcribed the curve *a* 2, from its conjunction, his ſecond the curve *b* 2, his third the curve *c* 2, and his fourth the curve *d* 2, and ſo on. The numeral Figures under the capital letters ſhew Jupiter's place in his path every day for 18 days, accounted from *A* to *T*; and the like Figures ſet to the paths of his Satellites, ſhew where they are at the like times. The firſt Satellites, almoſt under *C*, is ſtationary at +, as ſeen from the Sun; and retrograde from + to 2: at 2 it appears ſtationary again, and thence it moves forward until it has paſſed 3, and is twice ſtationary, and once retrograde between 3 and 4. The path of this Satellite interſects itſelf every 42½ hours, making ſuch Loops as in the Diagram at 2. 3. 5. 7. 9. 10. 12. 14. 16. 18, a little after every conjunction. The ſecond Satellite *b*, moving ſlower, barely croſſes its path every 3 days 13 hours; as at 4. 7. 11. 14. 18, making only 5 Loops and as many conjunctions in the time that the firſt makes ten. The third Satellite *c* moving ſtill ſlower, and having deſcribed the curve *c* 1. 2. 3. 4. 5. 6. 7, comes to an angle at 7, in conjunction with the Sun, at the end of 7 days four hours; and ſo goes on to deſcribe ſuch another curve 7. 8. 9. 10. 11. 12. 13. 14, and is at 14 in its next conjunction. The fourth Satellite *d* is always progreſſive, making neither Loops nor Angles in the Heavens; but comes to its next conjunction at *e* between the numeral figures 16 and 17, or in 16 days 18 hours. In order to have a tolerably good figure of the paths of theſe Satellites, I took the following method. Fig. III.

PLATE VII. Fig. IV.

Having drawn their Orbits on a Card, in proportion to their relative diſtances from Jupiter, I meaſured the radius of the Orbit of the fourth Satellite, which was an inch and $\frac{14}{100}$ parts of an inch; then multiplied this by 424 for the radius of Jupiter's Orbit, becauſe Jupiter is 424 times as far from the Sun's center as his fourth Satellite is from his center; and the product thence ariſing was 483 $\frac{36}{100}$ inches. Then taking a ſmall cord of this length, and fixing one end of it to the floor of a long room by a nail, with a black-lead pencil at the other end I drew the curve *ABCD*, &c. and ſet off a degree and half thereon, from *A* to *T*; becauſe Jupiter moves only ſo much, while his outermoſt Satellite goes once round him, and ſomewhat more; ſo that this ſmall portion of ſo large a circle differs but very little from a ſtraight line. This done, I divided the ſpace *AT* into 18 equal parts, as *AB*, *BC*, &c. for the daily progreſs of Jupiter; and each part into 24 for his hourly progreſs. The Orbit of each Satellite was alſo divided into as many equal parts as the Satellite is hours in finiſhing its ſynodical period round Jupiter. Then drawing a right line through the center of the Card, as a diameter to all the four Orbits upon it, I put the Card upon the line of Jupiter's motion, and transferred it to every horary diviſion thereon, keeping always the ſame diameter-line on the line of Jupiter's path; and running a pin through each horary diviſion in the Orbit of each Satellite as the Card was gradually transſerred along the line *ABCD*, &c. of Jupiter's motion, I marked points for every hour through the Card for the curves deſcribed by the Satellites, as the primary Planet in the center of the Card was carried forward on the line; and ſo finiſhed the Figure, by drawing the lines of each Satellite's motion through thoſe (almoſt innumerable) points: by which means, this is, perhaps, as true a Figure of the paths of theſe Satellites as can be deſired.

How to delineate the paths of Jupiter's Moons.

And

And in the ſame manner might thoſe of Saturn's Satellites be delineated. And Saturn's. PLATE VII.

270. It appears by the ſcheme, that the three firſt Satellites come almoſt into the ſame line of poſition every ſeventh day; the firſt being only a little behind with the ſecond, and the ſecond behind with the third. But the period of the fourth Satellite is ſo incommenſurate to the periods of the other three, that it cannot be gueſſed at by the diagram when it would fall again into a line of conjunction with them between Jupiter and the Sun. And no wonder; for ſuppoſing them all to have been once in conjunction, it will require 3,087,043,493,260 years to bring them in conjunction again. See § 73. The grand Periods of Jupiter's Moons.

271. In Fig. 4th, we have the proportions of the Orbits of Saturn's five Satellites, and of Jupiter's four, to one another, to our Moon's Orbit, and to the Diſc of the Sun. *S* is the Sun; *Mm* the Moon's Orbit (the Earth ſuppoſed to be at *E*); *J* Jupiter; 1. 2. 3. 4, the Orbits of his four Moons or Satellites; *Sat.* Saturn; and 1. 2. 3. 4. 5, the Orbits of his five Moons. Hence it appears, that the Sun would much more than fill the whole Orbit of the Moon; for the Sun's diameter is 763,000 miles, and the diameter of the Moon's Orbit only 480,000. In proportion to all theſe Orbits of the Satellites, the radius of Saturn's annual Orbit would be 21¼ yards, of Jupiter's Orbit 11⅔, and of the Earth's 2¼, taking them in round numbers. Fig. IV. The proportions of the Orbits of the Planets and Satellites.

272. The annexed Table ſhews at once what proportion the Orbits, Revolutions, and Velocities of all the Satellites bear to thoſe of their primary Planets, and what ſort of curves the ſeveral Satellites deſcribe. For thoſe Satellites, whoſe velocities round their Primaries are greater than the velocities of their Primaries in open ſpace, make Loops at their conjunctions, § 269; appearing retrograde as ſeen from the Sun while they deſcribe the

the inferior parts of their Orbits, and direct while they describe the superior. This is the case with Jupiter's first and second Satellites, and with Saturn's first. But those Satellites, whose velocities are less than the velocities of their primary Planets, move direct in their whole circumvolutions; which is the case of the third and fourth Satellites of Jupiter, and of the second, third, fourth, and fifth Satellites of Saturn, as well as of our Satellite the Moon: but the Moon is the only Satellite whose motion is always concave to the Sun. There is a table of this Sort in *De la Caille*'s Astronomy, but it is very different from the above, which I have computed from our *English* accounts of the periods and distances of these Planets and Satellites.

The Satellites		Proportion of the Radius of the Planet's Orbit to the Radius of the Orbit of each Satellite.	Proportion of the Time of the Planet's Revolution to the Revolution of each Satellite.	Proportion of the Velocity of each Satellite to the Velocity of its primary Planet.
of Saturn	1	As 5322 to 1	As 5738 to 1	As 5738 to 5322
	2	4155 1	3912 1	3912 4155
	3	2954 1	2347 1	2347 2954
	4	1295 1	674 1	674 1295
	5	432 1	134 1	134 432
of Jupiter	1	As 1851 to 1	As 2445 to 1	As 2445 to 1851
	2	1165 1	1219 1	1219 1165
	3	731 1	604 1	604 731
	4	424 1	258 1	258 424
The Moon		As 337½ to 1	As 12⅕ to 1	As 12⅓ to 337½

C H A P.

CHAP. XVI.

The Phenomena of the Harvest-Moon explained by a common Globe. The Years in which the Harvest-Moons are least and most beneficial from 1751 *to* 1861. *The long Duration of Moon-light at the Poles in Winter.*

273. IT is generally believed that the Moon rises about 50 minutes later every day than on the preceding; but this is true only with regard to places on the Equator. In places of considerable Latitude there is a remarkable difference, especially in the harvest-time, with which farmers were better acquainted than Astronomers till of late; and gratefully ascribed the early rising of the Full Moon at that time of the year to the goodness of God, not doubting that he had ordered it so on purpose to give them an immediate supply of moon-light after sun-set for their greater conveniency in reaping the fruits of the Earth. **No Harvest-Moon at the Equator.**

In this instance of the Harvest-Moon, as in many others discoverable by Astronomy, the wisdom and beneficence of the Deity is conspicuous, who really ordered the course of the Moon so, as to bestow more or less light on all parts of the Earth as their several circumstances and seasons render it more or less serviceable. About the Equator, where there is no variety of seasons, and the weather changes seldom, and at stated times, Moon-light is not necessary for gathering in the produce of the ground; and there the Moon rises about 50 minutes later every day or night than on the former. In considerable distances from the Equator, where the weather and seasons are more uncertain, the autumnal Full Moons rise very soon after sun-

set

But remarkable according to the diſtances of places from it.

ſet for ſeveral evenings together. At the polar circles, where the mild ſeaſon is of very ſhort duration, the autumnal Full Moon riſes at ſun-ſet from the firſt to the third quarter. And at the Poles, where the Sun is for half a year abſent, the winter Full Moons ſhine conſtantly without ſetting from the firſt to the third quarter.

The reaſon of this.

It is ſoon ſaid that all theſe Phenomena are owing to the different Angles made by the Horizon and different parts of the Moon's Orbit; and that the Moon can be full but once or twice in a year in thoſe parts of her Orbit which riſe with the leaſt Angles. But to explain this ſubject intelligibly, we muſt dwell much longer upon it.

274. The * plane of the Equinoctial is perpendicular to the Earth's Axis; and therefore, as the Earth turns round its Axis, all parts of the Equinoctial make equal angles with the Horizon both at riſing and ſetting; ſo that equal portions of it always riſe or ſet in equal times. Conſequently, if the Moon's motion were equable, and in the Equinoctial, at the rate of 12 degrees 11 min. from the Sun every day, as it is in her Orbit, ſhe would riſe and ſet 50 minutes later every day than on the preceding; for 12 deg. 11 min. of the Equinoctial riſe or ſet in 50 minutes of time in all Latitudes.

275. But the Moon's motion is ſo nearly in the Ecliptic, that we may conſider her at preſent as moving in it. Now the different parts of the Ecliptic, on account of its obliquity to the Earth's Axis, make very different angles with the Horizon as they riſe or ſet. Thoſe parts or Signs which riſe with the ſmalleſt angles ſet with the greateſt, and *vice verſa*. In equal times, whenever this Angle is leaſt, a greater portion of the Ecliptic riſes than when the Angle is larger; as may be ſeen by elevating the pole of a Globe to any con-

* If a Globe be cut quite through upon any Circle, the flat ſurface where it is ſo divided is the plane of that Circle.

ſiderable

ſiderable Latitude, and then turning it round its Axis. Conſequently, when the Moon is in thoſe Signs which riſe or ſet with the ſmalleſt Angles, ſhe riſes or ſets with the leaſt difference of time; and with the greateſt difference in thoſe Signs which riſe or ſet with the greateſt Angles. PLATE III. Fig. III.

But, becauſe all who read this Treatiſe may not be provided with Globes, though in this caſe it is requiſite to know how to uſe them, we ſhall ſubſtitute the Figure of a globe; in which *FUP* is the Axis, ♋ *TR* the Tropic of Cancer, *L t* ♑ the Tropic of Capricorn, ♋ *EU* ♑ the Ecliptic touching both the Tropics, which are 47 degrees from each other, and *AB* the Horizon. The Equator, being in the middle between the Tropics, is cut by the Ecliptic in two oppoſite points, which are the beginnings of ♈ Aries and ♎ Libra. *K* is the Hour-circle with its Index, *F* the North Pole of the Globe elevated to a conſiderable Latitude, ſuppoſe 40 degrees above the Horizon; and *P* the South Pole depreſſed as much below it. Becauſe of the oblique poſition of the Sphere in this Latitude, the Ecliptic has the high elevation *N* ♋ above the Horizon, making the Angle *NU* ♋ of 73½ degrees with it when ♋ Cancer is on the Meridian, at which time ♎ Libra riſes in the Eaſt. But let the Globe be turned half round its Axis, till ♑ Capricorn comes to the Meridian and ♈ Aries riſes in the Eaſt, and then the Ecliptic will have the low elevation *NL* above the Horizon, making only an Angle *NUL* of 26½ degrees with it; which is 47 degrees leſs than the former Angle, equal to the diſtance between the Tropics. Fig. III. The different Angles made by the Ecliptic and Horizon.

276. In northern Latitudes, the ſmalleſt Angle made by the Ecliptic and Horizon is when Aries riſes, at which time Libra ſets; the greateſt when Libra riſes, at which time Aries ſets. From the riſing of Aries to the riſing of Libra (which is twelve Leaſt and greateſt, when.

twelve * Sydereal hours) the angle increaſes; and from the riſing of Libra to the riſing of Aries it decreaſes in the ſame proportion. By this article and the preceding it appears that the Ecliptic riſes faſteſt about Aries, and ſloweſt about Libra.

Reſult of the quantity of this Angle at London.

277. On the parallel of *London*, as much of the Ecliptic riſes about Piſces and Aries in two hours as the Moon goes through in ſix days: and therefore while the Moon is in theſe Signs, ſhe differs but two hours in riſing for ſix days together; that is, about 20 minutes later every day or night than on the preceding, at a mean rate. But in fourteen days afterward, the Moon comes to Virgo and Libra, which are the oppoſite Signs to Piſces and Aries; and then ſhe differs almoſt four times as much in riſing; namely, one hour and about fifteen minutes later every day or night than the former, while ſhe is in theſe Signs. The annexed Table ſhews the daily mean difference of the Moon's riſing and ſetting on the Parallel of *London*, for 28 days;

Days.	Signs.	Degrees.	Riſing Diff. H.	Riſing Diff. M.	Setting Diff. H.	Setting Diff. M.
1	♋	13	1	5	0	50
2		26	1	10	0	43
3	♌	10	1	14	0	37
4		23	1	17	0	32
5	♍	6	1	16	0	28
6		19	1	15	0	24
7	♎	2	1	15	0	20
8		15	1	15	0	18
9		28	1	15	0	17
10	♏	12	1	15	0	22
11		25	1	14	0	30
12	♐	8	1	13	0	39
13		21	1	10	0	47
14	♑	4	1	4	0	56
15		17	0	46	1	5
16	♒	1	0	40	1	8
17		14	0	35	1	12
18		27	0	30	1	15
19	♓	10	0	25	1	16
20		23	0	20	1	17
21	♈	7	0	17	1	16
22		20	0	17	1	15
23	♉	3	0	20	1	15
24		16	0	24	1	15
25		29	0	30	1	14
26	♊	13	0	40	1	13
27		26	0	56	1	7
28	♋	9	1	00	0	58

* The Ecliptic, together with the fixed Stars, make $366\frac{1}{4}$ apparent diurnal revolutions about the Earth in a year; the Sun only $365\frac{1}{4}$. Therefore the Stars gain 3 minutes 56 ſeconds upon the Sun every Day; ſo that a Sydereal day contains only 23 hours 56 minutes of mean Solar time; and a natural or Solar day 24 hours. Hence 12 Sydereal hours are one minute 58 ſeconds ſhorter than 12 Solar hours.

in

in which time the Moon finishes her period round the Ecliptic, and gets 9 degrees into the same Sign from the beginning of which she set out. So it appears by the Table, that when the Moon is in ♍ and ♎ she rises an hour and a quarter later every day than she rose on the former; and differs only 28, 24, 20, 18, or 17 minutes in setting. But, when she comes to ♓ and ♈, she is only 20 or 17 minutes later in rising; and an hour and a quarter later in setting. PLATE III.

278. All these things will be made plain by putting small patches on the Ecliptic of a Globe, as far from one another as the Moon moves from any point of the celestial Ecliptic in 24 hours, which at a mean rate is * $13\frac{1}{6}$ degrees; and then in turning the Globe round, observe the rising and setting of the patches in the Horizon, as the Index points out the different times in the hour-circle. A few of these patches are represented by dots at 0 1 2 3, &c. on the Ecliptic, which has the position *LUI* when Aries rises in the East; and by the dots 0 1 2 3, &c. when Libra rises in the East, at which time the Ecliptic has the position *EU*♑: making an angle of 62 degrees with the Horizon in the latter case, and an angle of no more than 15 degrees with it in the former; supposing the Globe rectified to the Latitude of *London*. Fig. III.

279. Having rectified the Globe, turn it until the patch at 0, about the beginning of ♓ Pisces in the half *LUI* of the Ecliptic, comes to the Eastern side of the Horizon; and then keeping the ball steady, set the hour-index to XII, because *that* hour may perhaps be more easily remembered than any other. Then turn the Globe round West-

* The Sun advances almost a degree in the Ecliptic in 24 hours, the same way that the Moon moves; and therefore the Moon by advancing $13\frac{1}{6}$ degrees in that time goes little more than 12 degrees farther from the Sun than she was on the day before.

ward,

ward; and in that time, suppose the patch o to have moved thence to 1, $13\frac{1}{6}$ degrees, while the Earth turns once round its Axis, and you will see that 1 rises only about 20 minutes later than o did on the day before. Turn the Globe round again; and in that time suppose the same patch to have moved from 1 to 2; and it will rise only 20 minutes later by the hour-index than it did at 1 on the day or turn before. At the end of the next turn suppose the patch to have gone from 2 to 3 at *U*, and it will rise 20 minutes later than it did at 2. And so on for six turns, in which time there will scarce be two hours difference; nor would there have been so much, if the 6 degrees of the Sun's motion in that time had been allowed for. At the first turn the patch rises South of the East, at the middle turn due East, and at the last turn North of the East. But these patches will be 9 hours in setting on the Western side of the Horizon, which shews that the Moon's setting will be so much retarded in that week in which she moves through these two Signs. The cause of this difference is evident; for Pisces and Aries make only an Angle of 15 degrees with the Horizon when they rise; but they make an Angle of 62 degrees with it when they set. As the Signs Taurus, Gemini, Cancer, Leo, Virgo, and Libra, rise successively, the Angle increases gradually which they make with the Horizon, and decreases in the same proportion as they set. And for that reason, the Moon differs gradually more in the time of her rising every day while she is in these Signs, and less in her setting: after which, through the other six Signs, *viz.* Scorpio, Sagittary, Capricorn, Aquarius, Pisces, and Aries, the rising difference becomes less every day, until it be at the least of all, namely, in Pisces and Aries.

280. The Moon goes round the Ecliptic in 27 days 8 hours: but not from Change to Change in less than 29 days 12 hours: so that she is in Pisces and

and Aries at leaſt once in every Lunation, and in ſome Lunations twice.

Why the Moon is always Full in different Signs.

281. If the Earth had no annual motion, the Sun would never appear to ſhift his place in the Ecliptic. And then every New Moon would fall in the ſame ſign and degree of the Ecliptic, and every Full Moon in the oppoſite; for the Moon would go preciſely round the Ecliptic from Change to Change. So that if the Moon were once Full in Piſces or Aries, ſhe would always be Full when ſhe came round to the ſame Sign and Degree again. And as the Full Moon riſes at Sun-ſet (becauſe when any point of the Ecliptic ſets, the oppoſite point riſes) ſhe would conſtantly riſe within two hours of Sun-ſet, on the parallel of *London*, during the week in which ſhe were Full. But in the time that the Moon goes round the Ecliptic from any conjunction or oppoſition, the Earth goes almoſt a Sign forward: and therefore the Sun will ſeem to go as far forward in that time, namely, $27\frac{1}{2}$ degrees; ſo that the Moon muſt go $27\frac{1}{2}$ degrees more than round, and as much farther as the Sun advances in that interval, which is $2\frac{1}{15}$ degrees, before ſhe can be in conjunction with, or oppoſite to the Sun again. Hence it is evident, that there can be but one conjunction or oppoſition of the Sun and Moon in a year in any particular part of the Ecliptic. This may be familiarly exemplified by the hour and minute-hands of a watch, which are never in conjunction or oppoſition in that part of the dial-plate where they were ſo laſt before. And indeed if we compare the twelve hours on the dial-plate to the twelve ſigns of the Ecliptic, the hour-hand to the Sun, and the minute-hand to the Moon, we ſhall have a tolerably near reſemblance in miniature to the motions of our great celeſtial Luminaries. The only difference is, that while the Sun goes once round the Ecliptic, the Moon makes $12\frac{1}{3}$ conjunctions with him: but while the hour-hand goes round the

Her periodical and synodical Revolution exemplified.

P dial-

dial-plate, the minute-hand makes only 11 conjunctions with it; because the minute-hand moves slower in respect to the hour-hand than the Moon does with regard to the Sun.

The Harvest and Hunter's Moon.

282. As the Moon can never be full but when she is opposite to the Sun, and the Sun is never in Virgo and Libra but in our autumnal months, it is plain that the Moon is never full in the opposite Signs, Pisces and Aries, but in these two months. And therefore we can have only two Full Moons in the year, which rise so near the time of Sun-set for a week together, as above-mentioned. The former of these is called the *Harvest-Moon*, and the latter the *Hunter's Moon.*

Why the Moon's regular rising is never perceived but in Harvest.

283. Here it will probably be asked, why we never observe this remarkable rising of the Moon but in harvest, seeing she is in Pisces and Aries twelve times in the year besides; and must then rise with as little difference of time as in harvest? The answer is plain: for in winter these Signs rise at noon; and being then only a Quarter of a Circle distant from the Sun, the Moon in them is in her first Quarter: but when the Sun is above the Horizon, the Moon's rising is neither regarded nor perceived. In spring these Signs rise with the Sun, because he is then in them; and as the Moon changeth in them at that time of the year, she is quite invisible. In summer they rise about midnight, and the Sun being then three Signs, or a Quarter of a Circle before them, the Moon is in them about her third Quarter: when rising so late, and giving but very little light, her rising passes unobserved. And in autumn these Signs, being opposite to the Sun, rise when he sets, with the Moon in Opposition, or at the Full, which makes her rising very conspicuous.

284. At the Equator, the North and South Poles lie in the Horizon; and therefore the Ecliptic makes the same Angle southward with the Horizon

rizon when Aries rises, as it does northward when Libra rises. Consequently, as the Moon at all the fore-mentioned patches rises and sets nearly at equal Angles with the Horizon all the year round, and about 50 minutes later every day or night than on the preceding, there can be no particular Harvest-Moon at the Equator.

285. The farther that any place is from the Equator, if it be not beyond the Polar Circle, the Angle gradually diminishes which the Ecliptic and Horizon make when Pisces and Aries rise: and therefore when the Moon is in these Signs she rises with a nearly proportionable difference later every day than on the former; and is for that reason the more remarkable about the Full, until we come to the Polar Circles, or 66 degrees from the Equator; in which Latitude the Ecliptic and Horizon become coincident every day for a moment, at the same sydereal hour (or 3 minutes 56 seconds sooner every day than the former), and the very next moment one half of the Ecliptic containing Capricorn, Aquarius, Pisces, Aries, Taurus, and Gemini, rises, and the opposite half sets. Therefore, while the Moon is going from the beginning of Capricorn to the beginning of Cancer, which is almost 14 days, she rises at the same sydereal hour; and in autumn just at Sun-set, because all the half of the Ecliptic, in which the Sun is at that time, sets at the same sydereal hour, and the opposite half rises; that is, 3 minutes 56 seconds, of mean solar time, sooner every day than on the day before. So while the Moon is going from Capricorn to Cancer, she rises earlier every day than on the preceding; contrary to what she does at all places between the Polar Circles. But during the above fourteen days, the Moon is 24 sydereal hours later in setting; for the six Signs which rise all at once on the eastern side of the Horizon are 24 hours in setting on the western side of it; as any one may see by making chalk-marks

at the beginning of Capricorn and of Cancer, and then, having elevated the Pole 66½ degrees, turn the Globe ſlowly round its Axis, and obſerve the riſing and ſetting of the Ecliptic. As the beginning of Aries is equally diſtant from the beginning of Cancer and of Capricorn, it is in the middle of that half of the Ecliptic which riſes all at once. And when the Sun is at the beginning of Libra, he is in the middle of the other half. Therefore, when the Sun is in Libra, and the Moon in Capricorn, the Moon is a Quarter of a Circle before the Sun; oppoſite to him, and conſequently full in Aries, and a Quarter of a Circle behind him, when in Cancer. But when Libra riſes, Aries ſets, and all that half of the Ecliptic of which Aries is the middle, and therefore, at that time of the year, the Moon riſes at Sun-ſet from her firſt to her third Quarter.

The Harveſt-Moons regular on both ſides of the Equator.

286. In northern Latitudes, the autumnal Full Moons are in Piſces and Aries; and the vernal Full Moons in Virgo and Libra: in ſouthern Latitudes, juſt the reverſe, becauſe the ſeaſons are contrary. But Virgo and Libra riſe at as ſmall Angles with the Horizon in ſouthern Latitudes, as Piſces and Aries do in the northern; and therefore the Harveſt-Moons are juſt as regular on one ſide of the Equator as on the other.

287. As theſe Signs, which riſe with the leaſt Angles, ſet with the greateſt, the vernal Full Moons differ as much in their times of riſing every night, as the autumnal Full Moons differ in their times of ſetting; and ſet with as little difference as the autumnal Full Moons riſe: the one being in all caſes the reverſe of the other.

288. Hitherto, for the ſake of plainneſs, we have ſuppoſed the Moon to move in the Ecliptic, from which the Sun never deviates. But the Orbit in which the Moon really moves is different from the Ecliptic: one half being elevated 5⅓ degrees above it, and the other half as much depreſſed

pressed below it. The Moon's Orbit therefore intersects the Ecliptic in two points diametrically opposite to each other; and these intersections are called the *Moon's Nodes*. So the Moon can never be in the Ecliptic but when she is in either of her Nodes, which is at least twice in every course from Change to Change, and sometimes thrice. For, as the Moon goes almost a whole Sign more than round her Orbit from Change to Change; if she passes by either Node about the time of Change, she will pass by the other in about fourteen days after, and come round to the former Node two days again before the next Change. That Node from which the Moon begins to ascend northward, or above the Ecliptic, in northern latitudes, is called the *Ascending Node*; and the other the *Descending Node*, because the Moon, when she passes by it, descends below the Ecliptic southward.

The Moon's Nodes.

289. The Moon's oblique motion with regard to the Ecliptic causes some difference in the times of her rising and setting from what is already mentioned. For when she is northward of the Ecliptic, she rises sooner and sets later than if she moved in the Ecliptic; and when she is southward of the Ecliptic, she rises later and sets sooner. This difference is variable, even in the same Signs, because the Nodes shift backward about $19\frac{2}{3}$ degrees in the Ecliptic every year; and so go round it contrary to the order of Signs in 18 years 225 days.

290. When the ascending Node is in Aries, the southern half of the Moon's Orbit makes an Angle of $5\frac{1}{3}$ degrees less with the Horizon than the Ecliptic does, when Aries rises in northern Latitudes: for which reason the Moon rises with less difference of time while she is in Pisces and Aries, than she would do if she kept in the Ecliptic. But in 9 years and 112 days afterward, the Descending Node comes to Aries; and then the Moon's Orbit makes an Angle $5\frac{1}{3}$ degrees greater with the Horizon when Aries rises, than the

Ecliptic does at that time; which causes the Moon to rise with greater difference of time in Pisces and Aries than if she moved in the Ecliptic.

291. To be a little more particular; when the Ascending Node is in Aries, the Angle is only $9\frac{2}{3}$ degrees on the parallel of *London* when Aries rises. But when the Descending Node comes to Aries, the Angle is $20\frac{1}{3}$ degrees; this occasions as great a difference of the Moon's rising in the same Signs every 9 years, as there would be on two parallels $10\frac{2}{3}$ degrees from one another, if the Moon's course were in the Ecliptic. The following Table shews how much the Obliquity of the Moon's Orbit affects her rising and setting on the parallel of *London*, from the 12th to the 18th day of her age; supposing her to be full at the autumnal Equinox: and then, either in the Ascending Node, highest part of her Orbit, Descending Node, or lowest part of her Orbit. *M* signifies morning, *A* afternoon: and the line at the foot of the Table shews a week's difference in rising and setting.

Moon's Age	Full in her Ascending Node.		In the highest pt. of her Orbit.		Full in her Descending Node.		In the lowest pt. of her Orbit.	
	Rises at H. M	Sets at H. M.	Rises at H. M.	Sets at H. M.	Rises at H. M.	Sets at H. M.	Rises at H. M.	Sets at H. M.
12	5 *A* 15	3 *M* 20	4 *A* 30	3 *M* 15	4 *A* 32	3 *M* 40	5 *A* 16	3 *M* 0
13	5 32	4 25	4 50	4 45	5 15	4 20	6 0	4 15
14	5 48	5 30	5 15	6 0	5 45	5 40	6 20	5 28
15	6 5	7 0	5 42	7 20	6 15	6 56	6 45	6 32
16	6 20	8 15	6 2	8 35	6 46	8 0	7 8	7 45
17	6 36	9 12	6 26	9 45	7 18	9 15	7 30	9 15
18	6 54	10 30	7 0	10 40	8 0	10 20	7 52	10 0
Diff	13 9	7 10	2 30	7 25	3 28	6 40	2 36	7 0

This Table was not computed, but only estimated as near as could be done from a common Globe, on which the Moon's Orbit was delineated with a black-lead pencil. It may at first sight appear erroneous; since as we have supposed the Moon to be full in either Node at the autumnal Equinox, she ought by the Table to rise just at six o'clock, or at Sun-set, on the 15th day of her age; being in the Ecliptic at that time. But it must be considered, that the Moon is only $14\frac{3}{4}$ days old when she is Full; and therefore in both cases she is a little past the Node on the 15th day, being above it at one time, and below it at the other.

292. As there is a compleat revolution of the Nodes in $18\frac{2}{3}$ years, there must be a regular period of all the varieties which can happen in the rising and setting of the Moon during that time. But this shifting of the Nodes never affects the Moon's rising so much, even in her quickest descending Latitude, as not to allow us still the benefit of her rising nearer the time of Sun-set for a few days together about the Full in Harvest, than when she is Full at any other time of the year. The following Table shews in what years the Harvest-Moons are least beneficial as to the times of their rising, and in what years most, from 1751 to 1861. The column of years under the letter *L* are those in which the Harvest-Moons are least of all beneficial, because they fall about the Descending Node: and those under *M* are the most of all beneficial, because they fall about the Ascending Node. In all the columns from *N* to *S* the Harvest-Moons descend gradually in the Lunar Orbit, and rise to less heights above the Horizon. From *S* to *N* they ascend in the same proportion, and rise to greater heights above the Horizon. In both the Columns under *S*, the Harvest-Moons are in the lowest part of the Moon's Orbit, that is, farthest South of the Ecliptic; and therefore stay shortest of all above the Horizon: in the Columns under *N*, just the reverse. And in both cases, their risings, though not at the same times, are nearly the same with regard to difference of time, as if the Moon's Orbit were coincident with the Ecliptic.

The period of the Harvest-Moon.

Years in which the Harveſt-Moons are leaſt beneficial.									
N				L				S	
1751	1752	1753	1754	1755	1756	1757	1758	1759	
1770	1771	1772	1773	1774	1775	1776	1777	1778	
1788	1789	1790	1791	1792	1793	1794	1795	1796	1797
1807	1808	1809	1810	1811	1812	1813	1814	1815	
1826	1827	1828	1829	1830	1831	1832	1833	1834	
1844	1845	1846	1847	1848	1849	1850	1851	1852	
Years in which they are moſt beneficial.									
S				M				N	
1760	1761	1762	1763	1764	1765	1766	1767	1768	1769
1779	1780	1781	1782	1783	1784	1785	1786	1787	
1798	1799	1800	1801	1802	1803	1804	1805	1806	
1816	1817	1818	1819	1820	1821	1822	1823	1824	1825
1835	1836	1837	1838	1839	1840	1841	1842	1843	
1853	1854	1855	1856	1857	1858	1859	1860	1861	

293. At the Polar Circles, when the Sun touches the Summer Tropic, he continues 24 hours above the Horizon; and 24 hours below it when he touches the Winter Tropic. For the ſame reaſon the Full Moon neither riſes in Summer, nor ſets in Winter, conſidering her as moving in the Ecliptic. For the Winter Full Moon being as high in the Ecliptic as the Summer Sun, muſt therefore continue as long above the Horizon; and the Summer Full Moon being as low in the Ecliptic as the Winter Sun, can no more riſe than he does. But theſe are only the two Full Moons which happen about the Tropics, for all the others riſe and ſet. In Summer the Full Moons are low, and their ſtay is ſhort above the Horizon, when the nights are ſhort, and we have leaſt occaſion for Moon-light: in Winter they go high, and ſtay long above the Horizon, when the nights are long, and we want the greateſt quantity of Moon-light.

The long continuance of Moon-light at the Poles.

294. At the Poles, one half of the Ecliptic never ſets, and the other half never riſes: and therefore, as the Sun is always half a year in deſcribing one half of the Ecliptic, and as long in going through the other half, it is natural to imagine

Plate VIII.

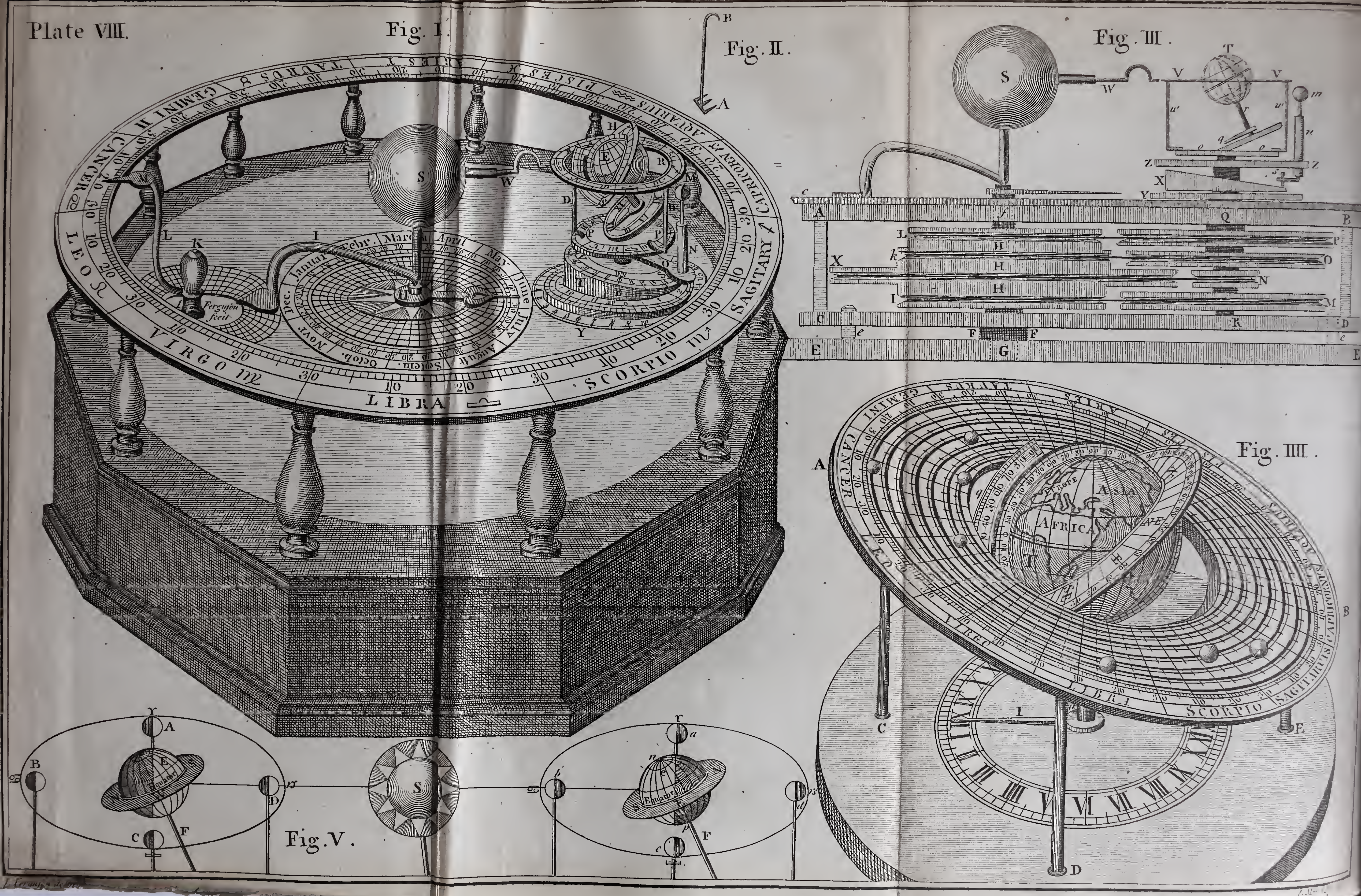


Fig. I.
Fig. II.
Fig. III.
Fig. IIII.
Fig. V.
Ferguson fecit
LIBRA
VIRGO
SCORPIO
LEO
CANCER
GEMINI
TAURUS
ARIES
PISCES
AQUARIUS
CAPRICORN
SAGITARY
ASIA
AFRICA
EUROPE

gine that the Sun continues half a year together above the Horizon of each Pole in its turn, and as long below it; rifing to one Pole when he fets to the other. This would be exactly the cafe if there were no refraction: but by the Atmofphere's refracting the Sun's rays, he becomes vifible fome days fooner, § 183, and continues fome days longer in fight than he would otherwife do: fo that he appears above the Horizon of either Pole before he has got below the Horizon of the other. And, as he never goes more than 23½ degrees below the Horizon of the Poles, they have very little dark night, it being twilight there, as well as at all other places, till the Sun be 18 degrees below the Horizon, § 177. The Full Moon being always oppofite to the Sun, can never be feen while the Sun is above the Horizon, except when the Moon falls in the northern half of her Orbit; for whenever any point of the Ecliptic rifes, the oppofite point fets. Therefore, as the Sun is above the Horizon of the north Pole from the 20th of *March* till the 23d of *September*, it is plain that the Moon, when Full, being oppofite to the Sun, muft be below the Horizon during that half of the year. But when the Sun is in the fouthern half of the Ecliptic, he never rifes to the north Pole, during which half of the year, every Full Moon happens in fome part of the northern half of the Ecliptic, which never fets. Confequently, as the polar Inhabitants never fee the Full Moon in Summer, they have her always in the Winter, before, at, and after the Full, fhining for 14 of our days and nights. And when the Sun is at his greateft depreffion below the Horizon, being then in Capricorn, the Moon is at her Firft Quarter in Aries, Full in Cancer, and at her Third Quarter in Libra. And as the beginning of Aries is the rifing point of the Ecliptic, Cancer the higheft, and Libra the fetting point, the Moon rifes at her Firft Quarter in Aries, is moft elevated above the Horizon,

PLATE VIII. Horizon, and Full in Cancer, and ſets at the beginning of Libra in her Third Quarter, having continued viſible for 14 diurnal rotations of the Earth. Thus the Poles are ſupplied one half of the winter-time with conſtant Moon-light in the Sun's abſence; and only loſe ſight of the Moon from her Third to her Firſt Quarter, while ſhe gives but very little light; and could be but of little, and ſometimes of no ſervice to them. A
Fig. V. bare view of the Figure will make this plain; in which let *S* be the Sun, *e* the Earth in Summer, when its north Pole *n* inclines toward the Sun, and *E* the Earth in Winter, when its north Pole declines from him. *SEN* and *NWS* is the Horizon of the north Pole, which is coincident with the Equator; and, in both theſe poſitions of the Earth, ♈ ♋ ♎ ♑ is the Moon's Orbit, in which ſhe goes round the Earth, according to the order of the letters *abcd*, *ABCD*. When the Moon is at *a*, ſhe is in her Third Quarter to the Earth at *e*, and juſt riſing to the north Pole *n*; at *b* ſhe changes, and is at the greateſt height above the Horizon, as the Sun likewiſe is; at *c* ſhe is in her Firſt Quarter, ſetting below the Horizon; and is loweſt of all under it at *d*, when oppoſite to the Sun, and her enlightened Side toward the Earth. But then ſhe is full in view to the ſouth Pole *p*; which is as much turned from the Sun as the north Pole inclines toward him. Thus in our Summer, the Moon is above the Horizon of the north Pole while ſhe deſcribes the northern half of the Ecliptic ♈ ♋ ♎, or from her Third Quarter to her Firſt; and below the Horizon during her progreſs through the ſouthern half ♎ ♑ ♈; higheſt at the Change, moſt depreſſed at the Full. But in winter, when the Earth is at *E*, and its north Pole declines from the Sun, the New Moon at *D* is at her greateſt depreſſion below the Horizon *NWS*, and the Full Moon at *B* at her greateſt height above it; riſing at her Firſt Quarter *A*, and

Plate IX.

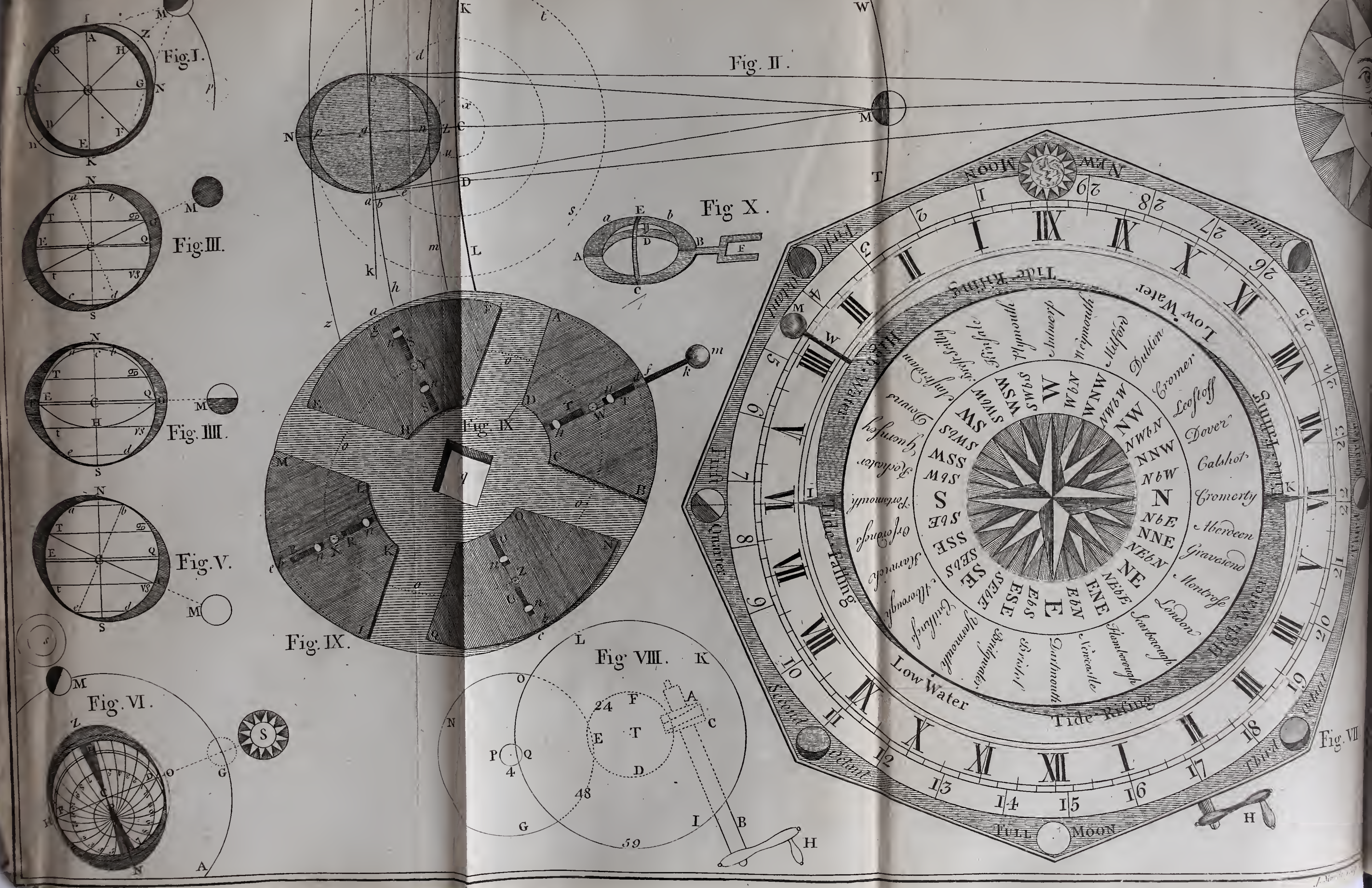


Fig. I.
Fig. II.
Fig. III.
Fig. IIII.
Fig. V.
Fig. VI.
Fig. VII
Fig. VIII.
Fig. IX.
Fig X.
New Moon
First Quarter
Full Moon
Third Quarter
Low Water
High Water
Tide Rising
Tide Falling
Dublin
Cromer
Leostoff
Dover
Calshot
Cromerty
Aberdeen
Gravesend
Montrose
London
Scarborough
Flamborough
Newcastle
Dartmouth
Bristol
Bridgwater
Yarmouth
Portsmouth
Guernsey
Milford
N
NbE
NNE
NEbN
NE
NEbE
ENE
EbN
E
EbS
ESE
SEbE
SE
SEbS
SSE
SbE
S
SbW
SSW
SWbS
SW
SWbW
WSW
WbS
W
WbN
WNW
NWbW
NW
NWbN
NNW
NbW

and keeping above the Horizon till ſhe comes to her third Quarter *C*. At a mean ſtate ſhe is $23\frac{1}{2}$ degrees above the Horizon at *B* and *b*, and as much below it at *D* and *d*, equal to the inclination of the Earth's Axis *F*. *S* ♋ or *S* ♑ are, as it were, a ray of light proceeding from the Sun to the Earth; and ſhews that when the Earth is at *e*, the Sun is above the Horizon, vertical to the Tropic of Cancer; and when the Earth is at *E*, he is below the Horizon, vertical to the Tropic of Capricorn.

CHAP. XVII.

Of the Ebbing and Flowing of the Sea.

295. THE cauſe of the Tides was diſcovered by KEPLER, who, in his *Introduction to the Phyſics of the Heavens*, thus explains it: "The Orb of the attracting power, which is in the Moon, is extended as far as the Earth; and draws the waters under the Torrid Zone, acting upon places where it is vertical, inſenſibly on confined ſeas and bays, but ſenſibly on the ocean, whoſe beds are large, and the waters have the liberty of reciprocation; that is, of riſing and falling." And in the 70th page of his *Lunar Aſtronomy*—"But the cauſe of the Tides of the Sea appears to be the bodies of the Sun and Moon drawing the waters of the Sea." This hint being given, the immortal Sir ISAAC NEWTON improved it, and wrote ſo amply on the ſubject, as to make the Theory of the Tides in a Manner quite his own; by diſcovering the cauſe of their riſing on the ſide of the Earth oppoſite to the Moon. For KEPLER believed, that the preſence of the Moon occaſioned an impulſe which cauſed another in her abſence.

The cauſe of the Tides diſcovered by KEPLER.

Their Theory improved by Sir ISAAC NEWTON.

296. It has been already ſhewn, § 106, that the power of gravity diminiſhes as the ſquare of the diſtance increaſes; and therefore the waters at *Z*, on

Explained on the Newtonian principles.

PLATE IX. Fig. I.

on the ſide of the Earth *ABCDEFGH* next the Moon *M*, are more attracted than the central parts of the Earth *O* by the Moon, and the central parts are more attracted by her than the waters on the oppoſite ſide of the Earth at *n*: and therefore the diſtance between the Earth's center and the waters on its ſurface under and oppoſite to the Moon will be increaſed. For, let there be three bodies at *H*, *O*, and *D*: if they are all equally attracted by the body *M*, they will all move equally faſt toward it, their mutual diſtances from each other continuing the ſame. If the attraction of *M* is unequal, then that body which is moſt ſtrongly attracted will move faſteſt, and this will increaſe its diſtance from the other body. Therefore, by the law of gravitation, *M* will attract *H* more ſtrongly than it does *O*, by which the diſtance between *H* and *O* will be increaſed: and a Spectator on *O* will perceive *H* riſing higher toward *Z*. In like manner *O* being more ſtrongly attracted than *D*, it will move farther toward *M* than *D* does: conſequently, the diſtance between *O* and *D* will be increaſed; and a ſpectator on *O*, not perceiving his own motion, will ſee *D* receding farther from him toward *n*: all effects and appearances being the ſame, whether *D* recedes from *O*, or *O* from *D*.

297. Suppoſe now there is a number of bodies, as *A*, *B*, *C*, *D*, *E*, *F*, *G*, *H*, placed round *O*, ſo as to form a flexible or fluid ring: then, as the whole is attracted towards *M*, the parts at *H* and *D* will have their diſtance from *O* increaſed; while the parts at *B* and *F*, being nearly at the ſame diſtance from *M* as *O* is, theſe parts will not recede from one another; but rather, by the oblique attraction of *M*, they will approach nearer to *O*. Hence, the fluid ring will form itſelf into an ellipſe *ZIBLnKFNZ*, whoſe longer Axis *nOZ* produced will paſs through *M*, and its ſhorter Axis *BOF* will terminate in *B* and *F*. Let the ring be filled

filled with fluid particles, so as to form a sphere round *O*; then, as the whole moves toward *M*, the fluid sphere being lengthened at *Z* and *n*, will assume an oblong or oval form. If *M* is the Moon, *O* the Earth's center, *ABCDEFGH* the Sea covering the Earth's surface, it is evident, by the above reasoning, that while the Earth by its gravity falls toward the Moon, the Water directly below her at *B* will swell and rise gradually toward her: also the Water at *D* will recede from the center [strictly speaking, the center recedes from *D*], and rise on the opposite side of the Earth: while the Water at *B* and *F* is depressed, and falls below the former level. Hence, as the Earth turns round its Axis from the Moon to the Moon again in 24¾ hours, there will be two Tides of Flood and two of Ebb in that time, as we find by Experience.

298. As this explanation of the ebbing and flowing of the Sea is deduced from the Earth's constantly falling toward the Moon by the power of gravity, some may find a difficulty in conceiving how this is possible, when the Moon is full, or in opposition to the Sun; since the Earth revolves about the Sun, and must continually fall toward it, and therefore cannot fall contrary ways at the same time: or if the Earth is constantly falling toward the Moon, they must come together at last. To remove this difficulty, let it be considered, that it is not the center of the Earth that describes the annual Orbit round the Sun, but the * common center of gravity of the Earth and Moon together: and that while the Earth is

* This center is as much nearer the Earth's center than the Moon's as the Earth is heavier, or contains a greater quantity of matter than the Moon, namely, about 40 times. If both bodies were suspended on it, they would hang in *equilibrio*. So that dividing 240,000 miles, the Moon's distance from the Earth's center, by 40, the excess of the Earth's weight above the Moon's, the quotient will be 6000 miles, which is the distance of the common center of gravity of the Earth and Moon from the Earth's center.

moving

PLATE IX. moving round the Sun, it alſo deſcribes a Circle round that center of gravity; going as many times round it in one revolution about the Sun as there are lunations or courſes of the Moon round the Earth in a year: and therefore, the Earth is conſtantly falling toward the Moon from a tangent to the Circle it deſcribes round the ſaid common center of gravity. Let *M* be the Moon, *TW* part of the Moon's Orbit, and *C* the center of gravity of the Earth and Moon; while the Moon goes round her Orbit, the center of the Earth deſcribes the Circle *dge* round *C*, to which Circle *gak* is a tangent: and therefore, when the Moon has gone from *M* to a little paſt *W*, the Earth has moved from *g* to *e*; and in that time has fallen toward the Moon, from the tangent at *a* to *e*; and ſo on, round the whole Circle.

Fig. II.

299. The Sun's influence in raiſing the Tides is but ſmall in compariſon of the Moon's: for though the Earth's diameter bears a conſiderable proportion to its diſtance from the Moon, it is next to nothing when compared to its diſtance from the Sun. And therefore, the difference of the Sun's attraction on the ſides of the Earth under and oppoſite to him, is much leſs than the difference of the Moon's attraction on the ſides of the Earth under and oppoſite to her: and therefore the Moon muſt raiſe the Tides much higher than they can be raiſed by the Sun.

Why the Tides are not higheſt when the Moon is on the Meridian.

300. On this Theory, ſo far as we have explained it, the Tides ought to be higheſt directly under and oppoſite to the Moon; that is, when the Moon is due north and ſouth. But we find, that in open Seas, where the water flows freely, the Moon *M* is generally paſt the north and ſouth Meridian, as at *p*, when it is high water at *Z* and at *n*. The reaſon is obvious; for though the Moon's attraction was to ceaſe altogether when ſhe was paſt the Meridian, yet the motion of aſcent communi-

Fig. I.

communicated to the water before that time would make it continue to riſe for ſome time after; much more muſt it do ſo when the attraction is only diminiſhed: as a little impulſe given to a moving ball will cauſe it ſtill to move farther than otherwiſe it could have done. And as experience ſhews, that the day is hotter about three in the afternoon than when the Sun is on the Meridian, becauſe of the encreaſe made to the heat already imparted.

PLATE IX.

Nor always anſwer to her being at the ſame diſtance from it.

301. The Tides anſwer not always to the ſame diſtance of the Moon from the Meridian at the ſame places; but are variouſly affected by the action of the Sun, which brings them on ſooner when the Moon is in her Firſt and Third Quarters, and keeps them back later when ſhe is in her Second and Fourth: becauſe, in the former caſe, the Tide raiſed by the Sun alone would be earlier than the Tide raiſed by the Moon; and in the latter caſe later.

Spring and neap Tides.

302. The Moon goes round the Earth in an elliptic Orbit, and therefore, in every Lunar Month, ſhe approaches nearer to the Earth than her mean diſtance, and recedes farther from it. When ſhe is neareſt, ſhe attracts ſtrongeſt, and ſo raiſes the Tides moſt; the contrary happens when ſhe is fartheſt, becauſe of her weaker attraction. When both Luminaries are in the Equator, and the Moon in *Perigeo*, or at her leaſt diſtance from the Earth, ſhe raiſes the Tides higheſt of all, eſpecially at her Conjunction and Oppoſition; both becauſe the equatorial parts have the greateſt centrifugal force from their deſcribing the largeſt Circle, and from the concurring actions of the Sun and Moon. At the change, the attractive forces of the Sun and Moon being united, they diminiſh the gravity of the waters under the Moon, and their gravity on the oppoſite ſide is diminiſhed by means of a greater centrifugal force. At the Full, while the Moon raiſes the Tide under and oppoſite to her, the Sun acting in the ſame line, raiſes the Tide under

Fig. VI.

under and oppoſite to him; whence their conjoin effect is the ſame as at the Change; and in both caſes, occaſion what we call the *Spring Tides.* But at the Quarters the Sun's action on the waters at *O* and *H* diminiſhes the effect of the Moon's action on the waters at *Z* and *N*; ſo that they riſe a little under and oppoſite to the Sun at *O* and *H*, and fall as much under and oppoſite to the Moon at *Z* and *N*; making what we call the *Neap Tides*, becauſe the Sun and Moon then act croſs-wiſe to each other. But, ſtrictly ſpeaking, theſe Tides happen not till ſome time after; becauſe in this, as in other caſes, § 300, the actions do not produce the greateſt effect when they are at the ſtrongeſt, but ſome time afterward.

Not greateſt at the Equinoxes, and why.

303. The Sun being nearer the Earth in Winter than in Summer, § 205, is of courſe nearer to it in *February* and *October*, than in *March* and *September*; and therefore the greateſt Tides happen not till ſome time after the autumnal Equinox, and return a little before the vernal.

The Tides would not immediately ceaſe upon the annihilation of the Sun and Moon.

The Sea being thus put in motion, would continue to ebb and flow for ſeveral times, even though the Sun and Moon were annihilated, or their influence ſhould ceaſe: as if a baſon of water were agitated, the water would continue to move for ſome time after the baſon was left to ſtand ſtill. Or like a pendulum, which having been put in motion by the hand, continues to make ſeveral vibrations without any new impulſe.

The lunar day, what. The Tides riſe to unequal heights in the ſame day, and why.

304. When the Moon is in the Equator, the Tides are equally high in both parts of the lunar day, or time of the Moon's revolving from the Meridian to the Meridian again, which is 24 hours 50 minutes. But as the Moon declines from the Equator toward either Pole, the Tides are alternately higher and lower at places having north or ſouth Latitude. For one of the higheſt elevations, which is that under the Moon, follows her toward the

the Pole to which ſhe is neareſt, and the other declines toward the oppoſite Pole; each elevation deſcribing parallels as far diſtant from the Equator, on oppoſite ſides, as the Moon declines from it to either ſide; and conſequently, the parallels deſcribed by theſe elevations of the water are twice as many degrees from one another as the Moon is from the Equator; increaſing their diſtance as the Moon increaſes her declination, till it be at the greateſt, when the ſaid parallels are, at a mean ſtate, 47 degrees from one another: and on that day the Tides are moſt unequal in their heights. As the Moon returns toward the Equator, the parallels deſcribed by the oppoſite elevations approach toward each other, until the Moon comes to the Equator, and then they coincide. As the Moon declines toward the oppoſite Pole, at equal diſtances, each elevation deſcribes the ſame parallel in the other part of the lunar day, which its oppoſite elevation deſcribed before. While the Moon has north declination, the greateſt Tides in the northern Hemiſphere are when ſhe is above the Horizon; and the reverſe while her declination is ſouth. Let *NESQ* be the Earth, *NCS* its Axis, *EQ* the Equator, *T* ♋ the Tropic of Cancer, *t* ♑ the Tropic of Capricorn, *ab* the arctic Circle, *cd* the antarctic, *N* the north Pole, *S* the ſouth Pole, *M* the Moon, *F* and *G* the two eminencies of water, whoſe loweſt parts are at *a* and *d* (Fig. III.) at *N* and *S* (Fig. IV.) and at *b* and *c* (Fig. V.) always 90 degrees from the higheſt. Now when the Moon is in her greateſt north declination at *M*, the higheſt elevation *G* under her, is on the Tropic of Cancer, *T* ♋, and the oppoſite elevation *F* on the Tropic of Capricorn, *t* ♑; and theſe two elevations deſcribe the Tropics by the Earth's diurnal rotation. All places in the northern Hemiſphere *ENQ* have the higheſt Tides when they come into the poſition *b* ♋ *Q*, under the Moon; and the loweſt Tides when the Earth's diurnal

PLATE IX.

Fig. III. IV. V.

Fig. III.

PLATE IX. rotation carries them into the position *aTE*, on the side opposite to the Moon; the reverse happens at the same time in the southern Hemisphere *EbQ*, as is evident to sight. The Axis of the Tides *aCd* has now its Poles *a* and *d* (being always 90 degrees from the highest elevations) in the arctic and antarctic Circles; and therefore it is plain, that at these Circles there is but one Tide of Flood, and one of Ebb, in the lunar day. For, when the point *a* revolves half round to *b*, in 12 lunar hours, it has a tide of Flood; but when it comes to the same point *a* again in 12 hours more, Fig. IV. it has the lowest Ebb. In seven days afterward, the Moon *M* comes to the equinoctial Circle, and is over the Equator *EQ*, when both elevations describe the Equator; and in both Hemispheres, at equal distances from the Equator, the Tides are equally high in both parts of the lunar day. The Fig. V. whole Phenomena being reversed, when the Moon has south declination, to what they were when her declination was north, require no farther description.

305. In the three last mentioned figures, the Earth is orthographically projected on the plane of the Meridian; but in order to describe a particular Phenomenon, we now project it on the plane of the Ecliptic. Let *HZON* be the Earth and Sea, Fig. VI. *FED* the Equator, *T* the Tropic of Cancer, *C* the arctic Circle, *P* the north Pole, and the Curves 1, 2, 3, &c. 24 Meridians, or Hour-circles, intersecting each other in the Poles; *AGM* is the Moon's Orbit, *S* the Sun, *M* the Moon, *Z* the Water elevated under the Moon, and *N* the opposite equal Elevation. As the lowest parts of the Water are always 90 degrees from the highest, when the Moon is in either of the Tropics (as at *M*) the Elevation *Z* is on the Tropic of Capricorn, and the opposite Elevation *N* on the Tropic of Cancer; the low-water Circle *HCO* touches the polar Circles at *C*, and the high-water Circle

When both Tides are equally high in the same day, they arrive at unequal intervals of Time; and *vice versâ*.

ETP 6

ETP 6 goes over the Poles at *P*, and divides every parallel of latitude into two equal ſegments. In this caſe the Tides upon every parallel are alternately higher and lower; but they return in equal times: the point *T*, for example, on the Tropic of Cancer (where the depth of the Tide is repreſented by the breadth of the dark ſhade) has a ſhallower Tide of Flood at *T*, than when it revolves half round from thence to 6, according to the order of the numeral Figures; but it revolves as ſoon from 6 to *T* as it did from *T* to 6. When the Moon is in the Equinoctial, the Elevations *Z* and *N* are transferred to the Equator at *O* and *H*, and the high and low-water Circles are got into each other's former places; in which caſe the Tides return in unequal times, but are equally high in both parts of the lunar day: for a place at 1 (under *D*) revolving as formerly, goes ſooner from 1 to 11 (under *F*) than from 11 to 1, becauſe the parallel it deſcribes is cut into unequal ſegments by the high-water Circle *HCO*: but the points 1 and 11 being equidiſtant from the Pole of the Tides at *C*, which is directly under the Pole of the Moon's Orbit *MGA*, the Elevations are equally high in both parts of the day.

306. And thus it appears, that as the Tides are governed by the Moon, they muſt turn on the Axis of the Moon's Orbit, which is inclined $23\frac{1}{2}$ degrees to the Earth's Axis at a mean ſtate: and therefore the Poles of the Tides muſt be ſo many degrees from the Poles of the Earth, or in oppoſite points of the polar Circles, going round theſe Circles in every lunar day. It is true, that according to Fig. IV. when the Moon is vertical to the Equator *ECQ*, the Poles of the Tides ſeem to fall-in with the Poles of the World *N* and *S*; but when we conſider that *FGH* is under the Moon's Orbit, it will appear, that when the Moon is over *H*, in the Tropic of Capricorn, the north Pole of

 the

the Tides (which can be no more than 90 degrees from under the Moon) muſt be at *C* in the arctic Circle, not at *P*, the north Pole of the Earth; and as the Moon aſcends from *H* to *G* in her Orbit, the north Pole of the Tides muſt ſhift from *c* to *a* in the arctic Circle, and the ſouth Pole as much in the antarctic.

It is not to be doubted, but that the Earth's quick rotation brings the Poles of the Tides nearer to the Poles of the World, than they would be if the Earth were at reſt, and the Moon revolved about it only once a month; for otherwiſe the Tides would be more unequal in their heights, and times of their returns, than we find they are. But how near the Earth's rotation may bring the Poles of its Axis and thoſe of the Tides together, or how far the preceding Tides may affect thoſe which follow, ſo as to make them keep up nearly to the ſame heights, and times of ebbing and flowing, is a problem more fit to be ſolved by obſervation than by theory.

To know at what times we may expect the greateſt and leaſt Tides.

307. Thoſe who have opportunity to make obſervations, and chooſe to ſatisfy themſelves whether the Tides are really affected in the above manner by the different poſitions of the Moon, eſpecially as to the unequal times of their returns, may take this general rule for knowing when they ought to be ſo affected. When the Earth's Axis inclines to the Moon, the northern Tides, if not retarded in their paſſage through Shoals and Channels, nor affected by the Winds, ought to be greateſt when the Moon is above the Horizon, leaſt when ſhe is below it; and quite the reverſe when the Earth's Axis declines from her: but in both caſes, at equal intervals of time. When the Earth's Axis inclines ſidewiſe to the Moon, both Tides are equally high, but they happen at unequal intervals of time. In every Lunation the Earth's Axis inclines once to the Moon, once from her, and

and twice ſidewiſe to her, as it does to the Sun every year: becauſe the Moon goes round the Ecliptic every Month, and the Sun but once in a year. In Summer, the Earth's Axis inclines toward the Moon when New; and therefore the day-tides in the north ought to be higheſt, and night-tides loweſt, about the Change: at the Full the reverſe. At the Quarters they ought to be equally high, but unequal in their returns; becauſe the Earth's Axis then inclines ſidewiſe to the Moon. In Winter, the Phenomena are the ſame at Full-Moon as in Summer at New. In Autumn, the Earth's Axis inclines ſidewiſe to the Moon when New and Full; therefore the Tides ought to be equally high and unequal in their returns at theſe times. At the Firſt Quarter, the Tides of Flood ſhould be leaſt when the Moon is above the Horizon, greateſt when ſhe is below it; and the reverſe at her third Quarter. In Spring, the Phenomena of the Firſt Quarter anſwer to thoſe of the Third Quarter in Autumn; and *vice verſâ*. The nearer any time is to either of theſe ſeaſons, the more the Tides partake of the Phenomena of theſe ſeaſons; and in the middle between any two of them the Tides are at a mean ſtate between thoſe of both.

308. In open Seas, the Tides riſe but to very ſmall heights in proportion to what they do in wide-mouthed rivers, opening in the Direction of the Stream of Tide. For, in Channels growing narrower gradually, the water is accumulated by the oppoſition of the contracting Bank. Like a gentle wind, little felt on an open plain, but ſtrong and briſk in a ſtreet; eſpecially if the wider end of the ſtreet be next the plain, and in the way of the wind.

Why the Tides riſe higher in Rivers than in the Sea.

309. The Tides are ſo retarded in their paſſage through different Shoals and Channels, and otherwiſe ſo variouſly affected by ſtriking againſt Capes and Headlands, that to different places they happen at all diſtances of the Moon from the Meridian; conſe-

The Tides happen at all diſtances of the Moon from the Meridian at different places, and why.

consequently at all hours of the lunar day. The Tide propagated by the Moon in the *German* Ocean, when she is three hours past the Meridian, takes 12 hours to come from thence to *London-bridge*; where it arrives by the time that a new Tide is raised in the Ocean. And therefore when the Moon has north declination, and we should expect the Tide at *London* to be greatest when the Moon is above the Horizon, we find it is least; and the contrary when she has south declination. At several places it is high-water three hours before the Moon comes to the Meridian; but that Tide which the Moon pushes as it were before her, is only the Tide opposite to that which was raised by her when she was nine hours past the opposite Meridian.

The Water never rises in Lakes.

310. There are no Tides in Lakes, because they are generally so small, that when the Moon is vertical she attracts every part of them alike, and therefore by rendering all the water equally light no part of it can be raised higher than another. The *Mediterranean* and *Baltic* Seas have very small elevations, because the Inlets by which they communicate with the Ocean are so narrow, that they cannot, in so short a time, receive or discharge enough to raise or sink their surfaces sensibly.

The Moon raises Tides in the Air.

311. Air being lighter than Water, and the surface of the Atmosphere being nearer to the Moon than the surface of the Sea, it cannot be doubted that the Moon raises much higher Tides in the Air than in the Sea. And therefore many have wondered why the Mercury does not sink in the Barometer when the Moon's action on the particles of Air makes them lighter as she passes over the Meridian. But we must consider, that as these particles are rendered lighter, a greater number of them is accumulated, until the deficiency of gravity be made up by the height of the column; and then there is an *equilibrium*, and consequently

Why the Mercury in the Barometer is not affected by the aërial Tides.

ſequently an equal preſſure upon the Mercury as before; ſo that it cannot be affected by the aërial Tides.

CHAP. XVIII.

Of Eclipſes: Their Number and Periods. A large Catalogue of Ancient and Modern Eclipſes.

312. EVERY Planet and Satellite is illuminated by the Sun, and caſts a ſhadow toward that point of the Heavens which is oppoſite to the Sun. This ſhadow is nothing but a privation of light in the ſpace hid from the Sun by the opake body that intercepts his rays. A ſhadow, what.

313. When the Sun's light is ſo intercepted by the Moon, that to any place of the Earth the Sun appears partly or wholly covered, he is ſaid to undergo an Eclipſe; though, properly ſpeaking, it is only an Eclipſe of that part of the Earth where the Moon's ſhadow or * Penumbra falls. When the Earth comes between the Sun and Moon, the Moon falls into the Earth's ſhadow; and having no light of her own, ſhe ſuffers a real Eclipſe from the interception of the Sun's rays. When the Sun is eclipſed to us, the Moon's Inhabitants on the ſide next the Earth (if any ſuch there be) ſee her ſhadow like a dark ſpot travelling over the Earth, about twice as faſt as its equatorial parts move, and the ſame way as they move. When the Moon is in an Eclipſe, the Sun appears eclipſed to her, total to all thoſe parts on which the Earth's ſhadow falls, and of as long continuance as they are in the ſhadow. Eclipſes of the Sun and Moon, what.

314. That the Earth is ſpherical (for the hills take off no more from the roundneſs of the Earth, than grains of duſt do from the roundneſs of a A proof that the Earth and Moon are globular bodies.

* The Penumbra is a faint kind of ſhadow all around the perfect ſhadow of the Planet or Satellite, and will be more fully explained by and by.

 common

common Globe) is evident from the figure of its ſhadow on the Moon; which is always bounded by a circular line, although the Earth is inceſſantly turning its different ſides to the Moon, and very ſeldom ſhews the ſame ſide to her in different Eclipſes, becauſe they ſeldom happen at the ſame hours. Were the Earth ſhaped like a round flat plate, its ſhadow would only be circular when either of its ſides directly faced the Moon; and more or leſs elliptical as the Earth happened to be turned more or leſs obliquely toward the Moon when ſhe is eclipſed. The Moon's different Phaſes prove her to be round, § 254; for, as ſhe keeps ſtill the ſame ſide toward the Earth, if that ſide were flat, as it appears to be, ſhe would never be viſible from the Third Quarter to the Firſt; and from the Firſt Quarter to the Third, ſhe would appear as round as when we ſay ſhe is Full: becauſe at the end of her Firſt Quarter the Sun's light would come as ſuddenly on all her ſide next the Earth, as it does on a flat wall, and go off as abruptly at the end of her Third Quarter.

And that the Sun is much bigger than the Earth, and the Moon much leſs.

315. If the Earth and Sun were equally big, the Earth's ſhadow would be infinitely extended, and all of the ſame bulk; and the Planet Mars, in either of its Nodes and oppoſite to the Sun, would be eclipſed in the Earth's ſhadow. Were the Earth bigger than the Sun, its ſhadow would increaſe in bulk the farther it extended, and would eclipſe the great Planets, Jupiter and Saturn, with all their Moons, when they were oppoſite to the Sun. But as Mars in oppoſition never falls into the Earth's ſhadow, although he is not then above 42 millions of miles from the Earth, it is plain that the Earth is much leſs than the Sun; for otherwiſe its ſhadow could not end in a point at ſo ſmall a diſtance. If the Sun and Moon were equally big, the Moon's ſhadow would go on to the Earth with an equal breadth, and cover a portion of the Earth's ſurface more than 2000 miles broad,

broad, even if it fell directly againſt the Earth's center, as ſeen from the Moon; and much more if it fell obliquely on the Earth: but the Moon's ſhadow is ſeldom 150 miles broad at the Earth, unleſs when it falls very obliquely on it in total Eclipſes of the Sun. In annular Eclipſes, the Moon's real ſhadow ends in a point at ſome diſtance from the Earth. The Moon's ſmall diſtance from the Earth, and the ſhortneſs of her ſhadow, prove her to be leſs than the Sun. And as the Earth's ſhadow is large enough to cover the Moon, if her diameter were three times as large as it is (which is evident from her long continuance in the ſhadow when ſhe goes through its center), it is plain that the Earth is much bigger than the Moon.

316. Though all opake bodies on which the Sun ſhines have their ſhadows, yet ſuch is the bulk of the Sun, and the diſtances of the Planets, that the primary Planets can never eclipſe one another. A Primary can eclipſe only its Secondary, or be eclipſed by it; and never but when in oppoſition or conjunction with the Sun. The primary Planets are very ſeldom in theſe poſitions, but the Sun and Moon are ſo every month: whence one may imagine that theſe two Luminaries ſhould be eclipſed every month. But there are few Eclipſes in reſpect of the number of New and Full Moons; the reaſon of which we ſhall now explain.

The primary Planets never eclipſe one another.

317. If the Moon's Orbit were coincident with the Plane of the Ecliptic, in which the Earth always moves, and the Sun appears to move, the Moon's ſhadow would fall upon the Earth at every Change, and eclipſe the Sun to ſome parts of the Earth. In like manner the Moon would go through the Middle of the Earth's ſhadow, and be eclipſed at every Full; but with this difference, that ſhe would be totally darkened for above an hour and an half; whereas the Sun never was above four minutes totally eclipſed by the interpoſition of

Why there are ſo few Eclipſes.

The Moon's Nodes. of the Moon. But one half of the Moon's Orbit is elevated $5\frac{1}{3}$ degrees above the Ecliptic, and the other half as much depressed below it: consequently, the Moon's Orbit intersects the Ecliptic in two opposite points called *the Moon's Nodes*, as has been already taken notice of, § 288. When these points are in a right line with the center of the Sun at New or Full Moon, the Sun, Moon, and Earth, are all in a right line; and if the Moon be then New, her shadow falls upon the Earth; if Full, the Earth's shadow falls upon her. When the Sun and Moon are more than 17 degrees from either of the Nodes at the time of Conjunction, Limits of Eclipses. the Moon is then generally too high or too low in her Orbit to cast any part of her shadow upon the Earth. And when the Sun is more than 12 degrees from either of the Nodes at the time of Full Moon, the Moon is generally too high or too low in her Orbit to go through any part of the Earth's shadow: and in both these cases there will be no Eclipse. But when the Moon is less than 17 degrees from either Node at the time of Conjunction, her shadow or Penumbra falls more or less upon the Earth, as she is more or less within this limit*. And when she is less than 12 degrees from either Node at the time of Opposition, she goes through a greater or less portion of the Earth's shadow as she is more or less within this limit. Her Orbit contains 360 degrees, of which 17, the limit of solar Eclipses on either side of the Nodes, and 12, the limit of lunar Eclipses, are but small portions: and as the Sun commonly passes by the Nodes but twice in a year, it is no wonder that

* This admits of some variation: for, in apogeal Eclipses, the solar limit is but $16\frac{1}{2}$ degrees; and in perigeal Eclipses it is $18\frac{1}{3}$.——When the Full Moon is in her Apogee, she will be eclipsed if she be within $10\frac{1}{2}$ degrees of the Node; and when she is full in her Perigee, she will be eclipsed if she be within $12\frac{1}{30}$ degrees of the Node.

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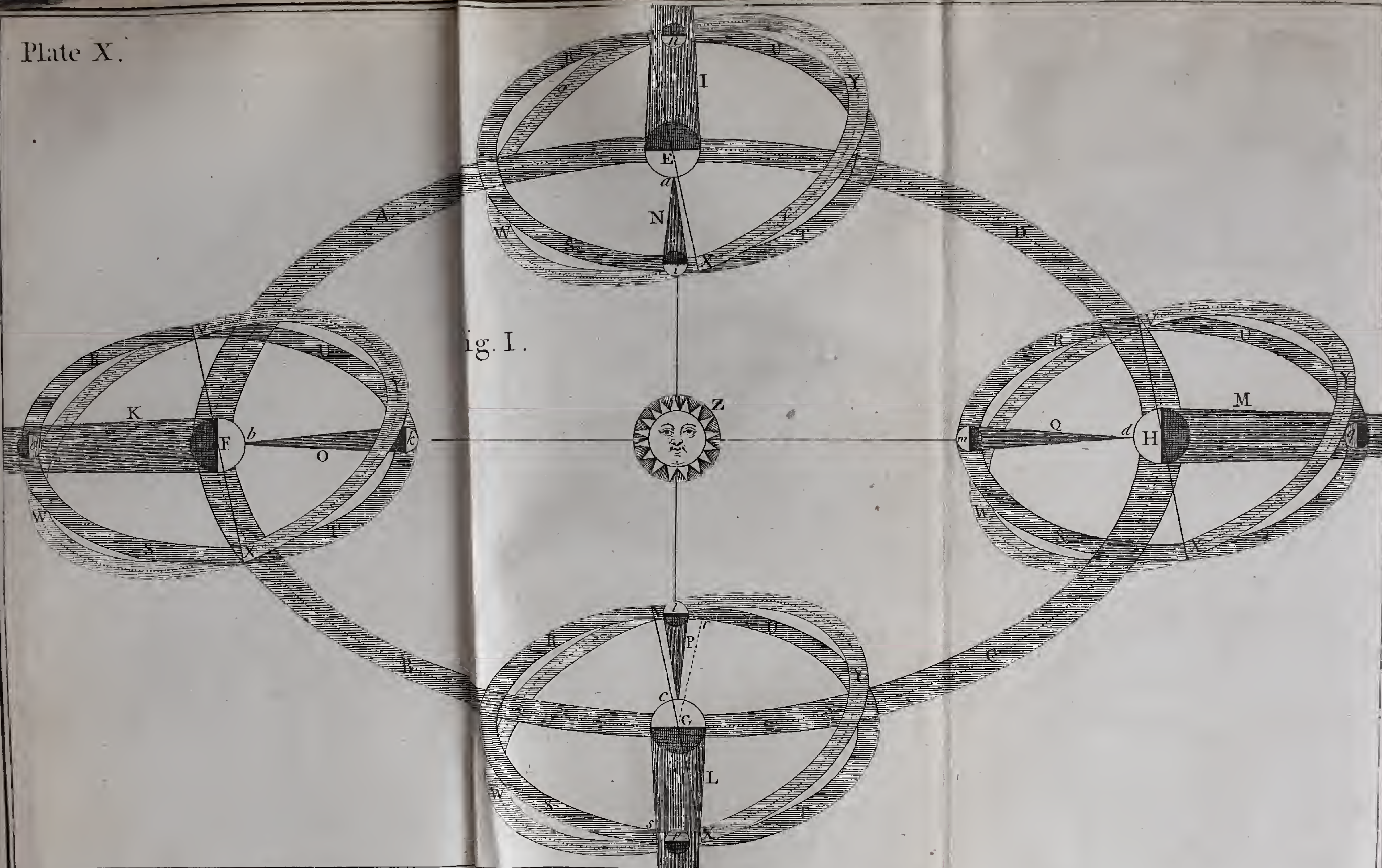
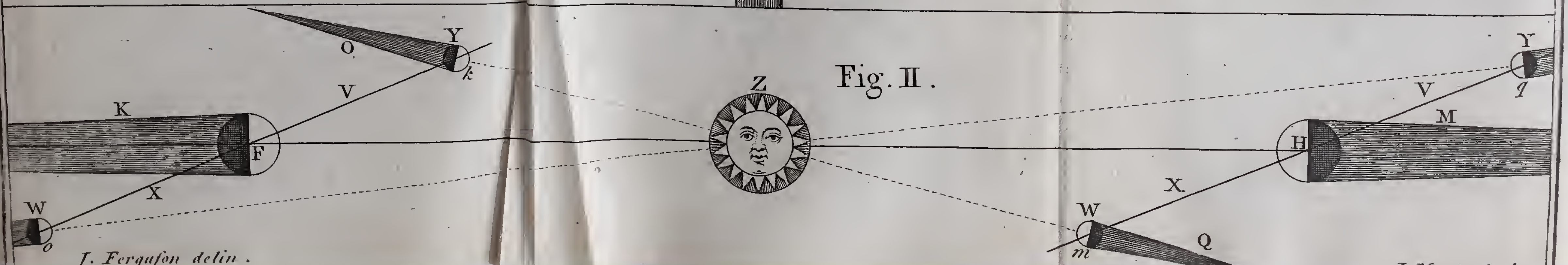
Plate X.





J. Ferguson delin.

J. Mynde sculp.

we have so many New and Full Moons without Eclipses. PLATE X.

To illustrate this, let *ABCD* be the *Ecliptic*, *RSTU* a Circle lying in the same Plane with the Ecliptic, and *VWXY* the *Moon's Orbit*, all thrown into an oblique view, which gives them an elliptical shape to the eye. One half of the Moon's Orbit, as *VWX*, is always below the Ecliptic, and the other half *XYV* above it. The points *V* and *X*, where the Moon's Orbit intersects the Circle *RSTU*, which lies even with the Ecliptic, are the *Moon's Nodes*; and a right line, as *XEV*, drawn, from one to the other, through the Earth's center, is called *the Line of the Nodes*, which is carried almost parallel to itself round the Sun in a year. Fig. I. Line of the Nodes.

If the Moon moved round the Earth in the Orbit *RSTU*, which is coincident with the Plane of the Ecliptic, her shadow would fall upon the Earth every time she is in conjunction with the Sun, and at every opposition she would go through the Earth's shadow. Were this the case, the Sun would be eclipsed at every Change, and the Moon at every Full, as already mentioned.

But although the Moon's shadow *N* must fall upon the Earth at *a*, when the Earth is at *E*, and the Moon in conjunction with the Sun at *i*, because she is then very near one of her Nodes; and at her opposition *n* she must go through the Earth's shadow *I*, because she is then near the other Node; yet, in the time that she goes round the Earth to her next Change, according to the order of the letters *XYVW*, the Earth advances from *E* to *e*, according to the order of the letters *EFGH*, and the line of the Nodes *VEX* being carried nearly parallel to itself, brings the point *f* of the Moon's Orbit in conjunction with the Sun at that next Change; and then the Moon being at *f*, is too high above the Ecliptic to cast her shadow on the Earth: and as the Earth is still moving forward, the Moon at her next opposition will be at *g*, too far

PLATE X. far below the Ecliptic to go through any part of the Earth's shadow; for by that time the point *g* will be at a considerable distance from the Earth as seen from the Sun.

When the Earth comes to *F*, the Moon in conjunction with the Sun *Z* is not at *k*, in a Plane coincident with the Ecliptic, but above it at *Y* in the highest part of her Orbit: and then the point *b* of her shadow *O* goes far above the Earth (as in Fig. II. which is an edge view of Fig. I.). The Fig. I. and II. Moon at her next opposition is not at *o* (Fig. I.) but at *W*, where the Earth's shadow goes far above her (as in Fig. II.). In both these cases the line of the Nodes *VFX* (Fig. I.) is about 90 degrees from the Sun, and both Luminaries are as far as possible from the limits of Eclipses.

When the Earth has gone half round the Ecliptic from *E* to *G*, the line of the Nodes *VGX* is nearly, if not exactly, directed toward the Sun at *Z*; and then the New Moon *l* casts her shadow *P* on the Earth *G*; and the Full Moon *p* goes through the Earth's shadow *L*; which brings on Eclipses again, as when the Earth was at *E*.

When the Earth comes to *H*, the New Moon falls not at *m* in a plane coincident with the Ecliptic *CD*, but at *W* in her Orbit below it: and then her shadow *Q* (see Fig. II.) goes far below the Earth. At the next Full she is not at *q* (Fig. I.) but at *Y* in her Orbit $5\frac{1}{3}$ degrees above *q*, and at her greatest height above the Ecliptic *CD*; being then as far as possible, at any opposition, from the Earth's shadow *M* (as in Fig. II.).

So, when the Earth is at *E* and *G*, the Moon is about her Nodes at New and Full; and in her greatest *north* and *south Declination* (or Latitude as it is generally called) from the Ecliptic at her Quarters: but when the Earth is at *F* or *H*, the Moon is in her greatest *north* and *south Declination* from the Ecliptic at New and Full, and in the *Nodes* about her Quarters.

318. The

318. The point X where the Moon's Orbit crosses the Ecliptic is called *the Ascending Node*, because the Moon ascends from it above the Ecliptic: and the opposite point of intersection V is called *the Descending Node*, because the Moon descends from it below the Ecliptic. When the Moon is at Y in the highest point of her Orbit, she is in her greatest *north Latitude*; and when she is at W in the lowest point of her Orbit, she is in her greatest *south Latitude*.

PLATE X. The Moon's ascending and descending Node.

Her north and south Latitude.

319. If the line of the Nodes, like the Earth's Axis, were carried parallel to itself round the Sun, there would be just half a year between the conjunctions of the Sun and Nodes. But the Nodes shift backward, or contrary to the Earth's annual motion, $19\frac{1}{3}$ degrees every year; and therefore the same Node comes round to the Sun 19 days sooner every year than on the year before. Consequently, from the time that the ascending Node X (when the Earth is at E) passes by the Sun as seen from the Earth, it is only 173 days (not half a year) till the descending Node V passes by him. Therefore, in whatever time of the year we have Eclipses of the Luminaries about either Node, we may be sure that in 173 days afterward we shall have Eclipses about the other Node. And when at any time of the year the line of the Nodes is in the situation VGX, at the same time next year it will be in the situation rGs; the ascending Node having gone backward, that is, contrary to the order of Signs, from X to s, and the descending Node from V to r; each $19\frac{1}{3}$ degrees. At this rate the Nodes shift through all the signs and degrees of the Ecliptic in 18 years and 225 days; in which time there would always be a regular period of Eclipses, if any complete number of Lunations were finished without a fraction. But this never happens; for if both the Sun and Moon should start from a line of conjunction with either of the Nodes in any point of the Ecliptic, the Sun would

The Nodes have a retrograde motion.

Fig. I.

Which brings on the Eclipses sooner every year than they would be if the Nodes had not such a motion.

perform 18 annual revolutions and 222 degrees over and above, and the Moon 230 Lunations and 85 degrees of the 231ſt, by the time the Node came round to the ſame point of the Ecliptic again: ſo that the Sun would then be 138 degrees from the Node, and the Moon 85 degrees from the Sun.

A period of Eclipſes. 320. But, in 223 mean Lunations, after the Sun, Moon, and Nodes have been once in a line of conjunction, they return ſo nearly to the ſame ſtate again, as that the ſame Node, which was in conjunction with the Sun and Moon at the beginning of the firſt of theſe Lunations, will be within 28′ 12″ of a degree of a line of conjunction with the Sun and Moon again, when the laſt of theſe Lunations is completed. And therefore, in that time, there will be a regular period of Eclipſes, or return of the ſame Eclipſe, for many ages.—In this period (which was firſt diſcovered by the *Chaldeans*) there are 18 *Julian* years 11 days 7 hours 43 minutes 20 ſeconds, when the laſt day of *February* in Leap-years is four times included: but when it is five times included, the period conſiſts of only 18 years 10 days 7 hours 43 minutes 20 ſeconds. Conſequently, if to the mean time of any Eclipſe, either of the Sun or Moon, you add 18 *Julian* years 11 days 7 hours 43 minutes 20 ſeconds, when the laſt day of *February* in Leap-years comes in four times, or a day leſs when it comes in five times, you will have the mean time of the return of the ſame Eclipſe.

But the falling back of the line of conjunctions or oppoſitions of the Sun and Moon 28′ 12″ with reſpect to the line of the Nodes in every period, will wear it out in proceſs of time; and after that, it will not return again in leſs than 12492 years.—Theſe Eclipſes of the Sun, which happen about the Aſcending Node, and begin to come in at the North Pole of the Earth, will go a little ſoutherly at each return, till they go quite off the Earth at the

the South Pole; and thoſe which happen about the Deſcending Node, and begin to come in at the South Pole of the Earth, will go a little northerly at each return, till at laſt they quite leave the Earth at the north Pole.

To exemplify this matter, we ſhall firſt conſider the Sun's Eclipſe, *March* 21ſt Old Stile (*April* 1ſt New Stile) A. D. 1764, according to its mean revolutions, without equating the times, or the Sun's diſtance from the Node; and then according to its true equated times.

This Eclipſe fell in the open ſpace at each return, quite clear of the Earth, ever ſince the creation till A. D. 1295, *June* 13th Old Stile, at 12 h. 52 m. 59 ſec *poſt meridiem*, when the Moon's ſhadow firſt touched the Earth at the North Pole; the Sun being then 17° 48′ 27″ from the Aſcending Node.—In each period ſince that time, the Sun has come 28′ 12″ nearer and nearer the ſame Node, and the Moon's ſhadow has therefore gone more and more ſoutherly.—In the year 1962, *July* 18th Old Stile, at 10 h. 36 m. 21 ſec. *p. m.* when the ſame Eclipſe will have returned 38 times, the Sun will be only 24′ 45″ from the Aſcending Node, and the center of the Moon's ſhadow will fall a little northward of the Earth's center.—At the end of the next following period, A. D. 1980 *July* 28th Old Stile, at 18 h. 19 m. 41 ſec. *p. m.* the Sun will have receded back 3′ 27″ from the Aſcending Node, and the Moon will have a very ſmall degree of ſouthern Latitude, which will cauſe the center of her ſhadow to paſs a very ſmall matter ſouth of the Earth's center.—After which, in every following period, the Sun will be 28′ 12″ farther back from the Aſcending Node than in the period laſt before; and the Moon's ſhadow will go ſtill farther and farther ſouthward, until *September* 12th Old Stile, at 23 h. 46 m. 22 ſec. *p. m.* A. D. 2665; when the Eclipſe will have completed its 77th periodical return, and will go quite

quite off the Earth at the South Pole (the Sun being then 17° 55′ 22″ back from the Node); and it cannot come in at the North Pole, so as to begin the same Course over again, in less than 12492 years afterward.—And such will be the case of every other Eclipse of the Sun: for as there is about 18 degrees on each side of the Node within which there is a possibility of Eclipses, their whole revolution goes through 36 degrees about that Node, which, taken from 360 degrees, leaves remaining 324 degrees for the Eclipses to travel *in expansum*. And as this 36 degrees is not gone through in less than 77 periods, which takes up 1388 years, the remaining 324 degrees cannot be so gone through in less than 12492 years. For, as 36 is to 1388, so is 324 to 12492.

321. In order to shew both the mean and true times of the returns of this Eclipse, through all its periods, together with the mean Anomalies of the Sun and Moon, at each return, and the mean and true distances of the Sun from the Moon's Ascending Node, and the Moon's true Latitude at the true time of each New Moon, I have calculated the following Tables for the sake of those who may choose to project this Eclipse at any of its returns, according to the rules laid down in the XVth Chapter; and have by that means taken by much the greatest part of the trouble off their hands.—All the times are according to the Old Stile, for the sake of a regularity which, with respect to the nominal days of the Months, does not take place in the New: but by adding the days difference of Stile, they are reduced to the times which agree with the New Stile.

According to the mean (or supposed equable) motions of the Sun, Moon, and Nodes, the Moon's shadow in this Eclipse would have first touched the Earth at the North Pole, on the 13th of *June*, A. D. 1295, at 12 h. 52 m. 59 sec. past noon on the Meridian of *London*; and would quite leave the Earth

Earth at the South Pole, on the 12th of *September*, A. D. 2665, at 23 h. 46 m. 22 sec. past Noon, at the completion of its 77th period; as shewn by the first and second Tables.

But, on account of the true (or unequable) motions of the Sun, Moon, and Nodes, the first coming in of this Eclipse, at the North Pole of the Earth, was on the 24th of *June*, A. D. 1313, at 3 h. 57 m. 3 sec. past Noon; and it will finally leave the Earth at the South Pole, on the 31st of *July*, A. D. 2593, at 10 h. 25 m. 31 sec. past Noon, at the completion of its 72d period; as shewn by the third and fourth Tables.—So that the true motions do not only alter the true times from the mean, but they also cut off five periods from those of the mean returns of this Eclipse.

TABLE I. *The mean Time of New Moon, with the mean Anomalies of the Sun and Moon, and the Sun's mean Distance from the Moon's Ascending Node, at the mean Time of each periodical Return of the Sun's Eclipse,* March 21*st*, 1764, *from its first coming upon the Earth since the Creation, till it falls right against the Earth's center, according to the Old Stile.*

Periodical Returns.	Years of Christ.	Mean Time of New Moon.					Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's mean Dist. from the Node.			
		Month	D.	H.	M.	S.	s	°	'	"	s	°	'	"	s	°	'	"
0	1277	June	2	5	9	39	11	17	57	41	1	26	31	42	0	18	16	40
1	1295	June	13	12	52	59	11	28	27	38	1	23	40	19	0	17	48	27
2	1313	June	23	20	36	19	0	8	57	35	1	20	48	56	0	17	20	15
3	1331	July	5	4	19	30	0	19	27	32	1	17	57	35	0	16	52	2
4	1349	July	15	12	2	59	0	29	57	29	1	15	6	10	0	16	23	50
5	1367	July	26	19	46	19	1	10	27	26	1	12	14	47	0	15	55	37
6	1385	Aug.	6	3	29	39	1	20	57	23	1	9	23	24	0	15	27	25
7	1403	Aug.	17	11	12	59	2	1	27	20	1	6	32	1	0	14	59	12
8	1421	Aug.	27	18	56	19	2	11	57	17	1	3	40	38	0	14	31	0
9	1439	Sept.	8	2	39	39	2	22	27	14	1	0	49	15	0	14	2	47
10	1457	Sept.	18	10	2	59	3	2	57	11	0	27	57	52	0	13	34	35
11	1475	Sept.	29	18	6	19	3	13	27	8	0	25	6	29	0	13	6	22
12	1493	Oct.	10	1	49	39	3	23	57	5	0	22	15	6	0	12	38	10
13	1511	Oct.	21	9	32	59	4	4	27	2	0	19	23	43	0	12	9	57
14	1529	Oct.	31	17	16	19	4	14	56	59	0	16	32	20	0	11	41	45
15	1547	Nov.	12	0	59	40	4	25	26	56	0	13	40	57	0	11	13	32
16	1565	Nov.	22	8	43	0	5	5	56	53	0	10	49	34	0	10	45	20
17	1583	Dec.	3	16	26	20	5	16	26	50	0	7	58	9	0	10	17	7
18	1601	Dec.	14	0	9	40	5	26	56	47	0	5	6	48	0	9	48	55
19	1619	Dec.	25	7	53	0	6	7	26	44	0	2	15	25	0	9	20	42
20	1638	Jan.	4	15	36	20	6	17	56	41	11	29	24	2	0	8	52	30
21	1656	Jan.	15	23	19	40	6	28	26	38	11	26	32	39	0	8	24	17
22	1674	Jan.	26	7	3	0	7	8	56	35	11	23	41	14	0	7	56	5
23	1692	Feb.	6	14	46	20	7	19	26	32	11	20	49	53	0	7	27	52
24	1710	Feb.	16	22	29	40	7	29	56	29	11	17	58	30	0	6	59	40
25	1728	Feb.	28	6	13	0	8	10	26	26	11	15	7	7	0	6	31	27
26	1746	Mar.	10	13	56	20	8	20	56	23	11	12	15	44	0	6	3	15
27	1764	Mar.	20	21	39	40	9	1	26	20	11	9	24	21	0	5	35	2
28	1782	Apr.	1	5	23	0	9	11	56	17	11	6	32	58	0	5	6	50
29	1800	Apr.	11	13	6	20	9	22	26	14	11	3	41	35	0	4	38	37
30	1818	Apr.	22	20	49	40	10	2	56	11	11	0	50	12	0	4	10	25
31	1836	May	3	4	33	0	10	13	26	8	10	27	58	49	0	3	42	12
32	1854	May	14	12	16	20	10	23	56	5	10	25	7	26	0	3	14	0
33	1872	May	24	19	59	40	11	4	26	2	10	22	16	3	0	2	45	47
34	1890	June	5	3	43	0	11	14	55	59	10	19	24	40	0	2	17	35
35	1908	June	15	11	20	20	11	25	25	56	10	16	33	17	0	1	49	22
36	1926	June	26	19	9	40	0	5	55	53	10	13	41	54	0	1	21	10
37	1944	July	7	2	53	0	0	16	25	50	10	10	50	31	0	0	52	57
38	1962	July	18	10	36	21	0	26	55	47	10	7	59	8	0	0	24	45

TABLE II *The mean Time of New Moon, with the mean Anomalies of the Sun and Moon, and the Sun's mean Distance from the Moon's Ascending Node, at the mean Time of each periodical Return of the Sun's Eclipse* March 21*st*, 1764, *from the mean Time of its falling right against the Earth's Center, till it finally leaves the Earth according to the Julian or Old Stile.*

Periodical Returns.	Years of Christ.	Mean Time of New Moon. Month.	D.	H.	M.	S.	Sun's mean Anomaly. s	°	'	"	Moon's mean Anomaly. s	°	'	"	Sun's mean Dist. from the Node. s	°	'	"
39	1980	July	28	18	19	41	1	7	25	44	10	5	7	45	11	29	56	33
40	1998	Aug.	9	2	3	1	1	17	55	41	10	2	16	22	11	29	28	20
41	2016	Aug.	19	9	46	21	1	28	25	38	9	29	24	59	11	29	0	8
42	2034	Aug.	30	17	29	41	2	8	55	36	9	26	33	36	11	28	31	55
43	2052	Sept.	10	1	13	1	2	19	25	33	9	23	42	13	11	28	3	43
44	2070	Sept.	21	8	56	21	2	29	55	32	9	20	50	50	11	27	35	30
45	2088	Oct.	1	16	39	41	3	10	25	27	9	17	59	27	11	27	7	18
46	2106	Oct.	13	0	23	1	3	20	55	24	9	15	8	4	11	26	39	5
47	2124	Oct.	23	8	6	21	4	1	25	21	9	12	16	41	11	26	10	53
48	2142	Nov.	3	15	49	41	4	11	55	18	9	9	25	18	11	25	42	40
49	2160	Nov.	13	23	31	1	4	22	25	15	9	6	33	56	11	25	14	28
50	2178	Nov.	25	7	16	21	5	2	55	12	9	3	42	33	11	24	40	15
51	2196	Dec.	5	14	59	41	5	13	25	9	9	0	51	10	11	24	18	3
52	2214	Dec.	16	22	43	1	5	23	55	7	8	27	59	47	11	23	49	50
53	2232	Dec.	27	6	26	21	6	4	25	4	8	25	8	24	11	23	21	38
54	2251	Jan.	7	14	9	41	6	14	55	1	8	22	17	1	11	22	53	25
55	2269	Jan.	17	21	53	1	6	25	24	58	8	19	25	38	11	22	15	13
56	2287	Jan.	29	5	36	21	7	5	54	55	8	16	31	15	11	21	57	0
57	2305	Feb.	8	13	19	41	7	16	24	52	8	13	42	52	11	21	28	48
58	2323	Feb.	19	21	3	1	7	26	54	49	8	10	51	29	11	21	0	35
59	2341	Mar.	2	4	46	21	8	7	24	46	8	8	0	6	11	20	32	23
60	2359	Mar.	13	12	29	42	8	17	54	43	8	5	8	43	11	20	4	10
61	2377	Mar.	23	20	13	2	8	28	24	40	8	2	17	20	11	19	35	58
62	2395	Apr.	4	3	56	22	9	8	54	37	7	29	25	57	11	19	7	45
63	2413	Apr.	14	11	39	42	9	19	24	34	7	26	34	34	11	18	39	33
64	2431	Apr.	25	19	23	2	9	29	54	31	7	23	43	11	11	18	11	20
65	2449	May	6	3	6	22	10	10	24	28	7	20	51	48	11	17	43	8
66	2467	May	17	10	49	42	10	20	54	25	7	18	0	25	11	17	14	54
67	2485	May	27	18	33	2	11	1	24	22	7	15	9	2	11	16	46	43
68	2503	June	8	2	16	22	11	11	54	19	7	12	17	39	11	16	18	31
69	2521	June	18	9	59	42	11	22	24	17	7	9	26	16	11	15	50	18
70	2539	June	29	17	43	2	0	2	54	14	7	6	34	53	11	15	22	6
71	2557	July	10	1	26	22	0	13	24	11	7	3	43	30	11	14	53	54
72	2575	July	21	9	9	42	0	23	54	8	7	0	52	7	11	14	25	41
73	2593	July	31	16	53	2	1	4	24	5	6	28	0	44	11	13	57	28
74	2611	Aug.	12	0	36	22	1	14	54	2	6	25	9	21	11	13	29	16
75	2629	Aug.	22	8	19	42	1	25	23	59	6	22	17	58	11	13	0	3
76	2647	Sept.	2	16	3	2	2	5	53	56	6	19	26	35	11	12	32	51
77	2665	Sept.	12	23	46	22	2	16	23	53	6	16	35	12	11	12	4	38

TABLE III. *The true Time of New Moon, with the Sun's true Distance from the Moon's Ascending Node, and the Moon's true Latitude, at the true Time of each periodical Return of the Sun's Eclipse,* March 21*st, Old Stile,* A. D. 1764, *from the Time of its first coming upon the Earth since the Creation till it falls right against the Earth's Center.*

Periodical Returns.	Years of Christ.	True Time of New Moon.					Sun's true Dist. from the Node.				Moon's true Latitude North.			
		Month.	D.	H.	M.	S	s	o	'	"	o	'	"	North.
0	1295	June	13	21	54	32	0	18	40	54	1	33	45	N. A.
1	1313	June	24	3	57	5	0	17	20	22	1	29	34	N. A.
2	1331	July	5	10	42	8	0	16	29	35	1	25	20	N. A.
3	1349	July	15	17	14	15	0	15	34	18	1	20	45	N. A.
4	1367	July	26	23	49	24	0	14	46	8	1	16	39	N. A.
5	1385	Aug.	6	6	41	17	0	13	59	43	2	12	43	N. A.
6	1403	Aug.	17	13	32	19	0	13	16	44	1	9	3	N. A.
7	1421	Aug.	27	20	30	17	0	12	37	4	1	5	42	N. A.
8	1439	Sept.	8	3	51	46	0	12	1	54	1	2	41	N. A.
9	1457	Sept.	18	10	23	11	0	11	30	27	0	58	53	N. A.
10	1475	Sept.	29	17	57	7	0	11	3	56	0	57	43	N. A.
11	1493	Oct.	10	1	44	3	0	10	41	55	0	55	49	N. A.
12	1511	Oct.	21	9	29	53	0	10	25	11	0	54	28	N. A.
13	1529	Oct.	31	17	9	18	0	10	11	27	0	53	12	N. A.
14	1547	Nov.	12	0	51	25	0	10	1	10	0	52	19	N. A.
15	1565	Nov.	22	8	54	56	0	9	52	49	0	51	46	N. A.
16	1583	Dec.	3	16	48	17	0	9	48	4	0	51	11	N. A.
17	1601	Dec.	14	0	51	5	0	9	43	42	0	50	49	N. A.
18	1619	Dec.	25	8	54	59	0	9	40	23	0	50	31	N. A.
19	1638	Jan.	4	16	56	1	0	9	34	57	0	50	3	N. A.
20	1656	Jan.	16	0	54	41	0	9	29	24	0	49	57	N. A.
21	1674	Jan.	26	8	48	24	0	9	19	44	0	48	44	N. A.
22	1692	Feb.	6	16	36	28	0	9	8	58	0	47	49	N. A.
23	1710	Feb.	17	0	8	37	0	8	54	20	0	46	44	N. A.
24	1728	Feb.	28	7	43	40	0	8	34	53	0	44	52	N. A.
25	1746	Mar.	10	15	14	33	0	8	10	38	0	42	46	N. A.
26	1764	Mar.	20	22	30	26	0	7	42	14	0	40	18	N. A.
27	1782	Apr.	1	5	37	4	0	7	9	27	0	37	28	N. A.
28	1800	Apr.	11	12	36	38	0	6	35	30	0	34	31	N. A,
29	1818	Apr.	22	19	27	34	0	5	51	48	0	30	43	N. A.
30	1836	May	3	2	12	7	0	5	5	5	0	26	40	N. A.
31	1854	May	14	8	50	40	0	4	19	45	0	22	42	N. A.
32	1872	May	24	15	28	15	0	3	26	3	0	18	1	N. A.
33	1890	June	4	22	8	0	0	2	35	5	0	13	34	N. A.
34	1908	June	15	4	38	23	0	1	41	43	0	8	54	N. A.
35	1926	June	26	11	13	5	0	0	47	38	0	4	10	N. A.

On account of the differences between the mean and true New Moons, and between the Sun's mean and true distances from the Node, the Moon's shadow falls even with the Earth's center two periods sooner in this Table than in the first.

TABLE IV. *The true Time of New Moon, with the Sun's true Distance from the Moon's Ascending Node and the Moon's true Latitude at each periodical Return of the Sun's Eclipse,* March 21*st*, *Old Stile*, A.D. 1764, *from its falling right against the Earth's Center, till it finally leaves the Earth.*

Periodical Returns.	Years of Christ.	True Time of New Moon.					Sun's true Dist. from the Node.				Moon's true Latitude South.			
		Month.	D.	H.	M.	S.	s	°	'	"	°	'	"	South.
36	1944	July	6	17	50	35	11	29	55	28	0	0	24	S. A.
37	1962	July	18	0	31	38	11	29	2	35	0	5	2	S. A.
38	1980	July	28	7	18	53	11	28	11	32	0	9	29	S. A.
39	1998	Aug.	8	14	12	22	11	27	26	41	0	13	25	S. A.
40	2016	Aug.	18	21	14	53	11	26	42	16	0	17	18	S. A.
41	2034	Aug.	30	4	25	45	11	26	2	0	0	20	48	S. A.
42	2052	Sept.	9	11	45	17	11	25	26	46	0	23	53	S. A.
43	2070	Sept.	20	19	17	26	11	24	55	4	0	26	39	S. A.
44	2088	Oct.	1	2	57	8	11	24	27	43	0	28	58	S. A.
45	2106	Oct.	12	10	47	39	11	24	4	38	0	31	2	S. A.
46	2124	Oct.	22	18	37	40	11	23	48	28	0	32	26	S. A.
47	2142	Nov.	3	2	56	19	11	23	35	11	0	33	53	S. A.
48	2160	Nov.	13	11	11	20	11	23	22	22	0	34	42	S. A.
49	2178	Nov.	24	19	36	14	11	23	18	57	0	35	0	S. A.
50	2196	Dec.	5	4	4	9	11	23	14	40	0	35	22	S. A.
51	2214	Dec.	16	12	35	48	11	23	10	43	0	35	43	S. A.
52	2232	Dec.	26	20	29	9	11	23	6	47	0	36	1	S. A.
53	2251	Jan.	7	5	42	9	11	23	4	27	0	36	16	S. A.
54	2269	Jan.	17	14	14	8	11	23	0	41	0	36	35	S. A.
55	2287	Jan.	28	22	43	34	11	22	53	58	0	37	10	S. A.
56	2305	Feb.	8	7	8	30	11	22	44	44	0	37	59	S. A.
57	2323	Feb.	19	15	7	10	11	22	31	1	0	39	8	S. A.
58	2341	Mar.	2	0	6	5	11	22	17	46	0	40	28	S. A.
59	2359	Mar.	13	7	59	17	11	21	55	29	0	42	9	S. A.
60	2377	Mar.	23	15	51	59	11	21	39	40	0	43	41	S. A.
61	2395	Apr.	3	23	45	7	11	21	0	53	0	46	58	S. A.
62	2413	Apr.	14	7	32	40	11	20	26	22	0	49	48	S. A.
63	2431	Apr.	25	15	12	57	11	19	47	34	0	53	17	S. A.
64	2449	May	5	22	45	14	11	19	6	22	0	56	50	S. A.
65	2467	May	17	6	17	30	11	18	21	16	1	0	40	S. A.
66	2485	May	27	13	46	29	11	17	34	20	1	4	42	S. A.
67	2503	June	7	21	10	31	11	16	43	17	1	9	3	S. A.
68	2521	June	18	4	24	42	11	15	51	48	1	13	26	S. A.
69	2539	June	29	11	58	46	11	15	1	12	1	17	43	S. A.
70	2557	July	9	19	24	7	11	14	9	13	1	22	6	S. A.
71	2575	July	21	2	52	34	11	13	19	22	1	26	16	S. A.
72	2593	July	31	10	25	31	11	12	13	43	1	31	44	S. A.
0	2611	Aug.	11	17	58	39	11	11	45	13	1	36	13	S. A.

By the true Motions of the Sun, Moon, and Nodes, this Eclipse goes off the Earth four Periods sooner than it would have done by mean equable Motions.

From Mr. G SMITH's Differtation on Eclipfes, printed at *London*, by E. CAVE, in the year 1748.

" To illuftrate this a little farther, we fhall exa-
" mine fome of the moft remarkable circumftances
" of the returns of the Eclipfe which happened
" *July* 14, 1748, about noon. This Eclipfe, after
" traverfing the voids of fpace from the Creation,
" at laft began to enter the *Terra Auftralis Incog-*
" *nita*, about 88 years after the Conqueft, which
" was the laft of King STEPHEN's reign; every
" *Chaldean* * period it has crept more northerly,
" but was ftill vifible in *Britain* before the year
" 1622; when on the 30th of *April* it began to
" touch the fouth parts of *England* about 2 in the
" afternoon: its central appearance rifing in the
" *American* South Seas, and traverfing *Peru* and
" the *Amazon*'s country, through the *Atlantic* ocean
" into *Africa*, and fetting in the *Ethiopian* conti-
" nent, not far from the beginning of the Red Sea.

" Its next vifible period was after three *Chaldean*
" revolutions in 1676, on the firft of *June*, rifing
" central in the *Atlantic* ocean, paffing us about
" 9 in the morning, with four † Digits eclipfed on
" the under limb; and fetting in the gulph of *Co-*
" *chinchina* in the *Eaft Indies*.

" It being now near the Solftice, this Eclipfe
" was vifible the very next return in 1694, in the
" evening; and in two periods more, which was
" in 1730, on the 4th of *July*, was feen above half
" eclipfed juft after Sun-rife, and obferved both
" at *Wittemberg* in *Germany*, and *Pekin* in *China*,
" foon after which it went off.

" Eighteen years more afforded us the Eclipfe
" which fell on the 14th of *July*, 1748.

" The next vifible return will happen on *July*
" 25, 1766, in the evening, about four Digits
" eclipfed; and after two periods more, on *Auguft*

* The above period of 18 years 11 days 7 hours 43 minutes 20 feconds, which was found out by the *Chaldeans*, and by them called *Saros*.

† A Digit is a twelfth part of the diameter of the Sun or Moon.

 " 16th,

" 16th, 1802, early in the morning, about five " Digits, the center coming from the north frozen " continent, by the capes of *Norway*, through " *Tartary*, *China*, and *Japan*, to the *Ladrone* " islands, where it goes off.

" Again, in 1820, *August* 26, betwixt one and " two, there will be another great Eclipse at *London*, " about 10 Digits; but happening so near the " Equinox, the center will leave every part of " *Britain* to the West, and enter *Germany* at *Emb-* " *den*, passing by *Venice*, *Naples*, *Grand Cairo*, and " set in the gulph of *Bassora* near that city.

" It will be no more visible till 1874, when five " Digits will be obscured (the center being now " about to leave the Earth) on *September* 28. In " 1892 the Sun will go down eclipsed at *London*, " and again in 1928 the passage of the center will " be in the *expansum*, though there will be two " Digits eclipsed at *London*, *October* the 31st of " that year; and about the year 2090 the whole " Penumbra will be wore off; whence no more " returns of this Eclipse can happen till after a re- " volution of 10 thousand years.

" From these remarks on the intire revolution " of this Eclipse, we may gather, that a thousand " years, more or less (for there are some irregula- " rities that may protract or lengthen this period " 100 years), complete the whole terrestrial Phe- " nomena of any single Eclipse: and since 20 pe- " riods of 54 years each, and about 33 days, com- " prehend the entire extent of their revolution, it " is evident that the times of the returns will pass " through a circuit of one year and ten months, " every *Chaldean* period being ten or eleven days " later, and of the equable appearances about 32 " or 33 days. Thus, though this Eclipse happens " about the middle of *July*, no other subsequent " Eclipse of this period will return to the middle " of the same month again; but wear, constantly " each period 10 or 11 days forward; and at last

" appear in Winter, but then it begins to ceafe " from affecting us.

" Another conclufion from this revolution may " be drawn, that there will feldom be any more " than two great Eclipfes of the Sun in the interval " of this period, and thefe follow fometimes next " return, and often at greater diftances. That of " 1715 returned again in 1733 very great; but " this prefent Eclipfe will not be great till the " arrival of 1820, which is a revolution of four " *Chaldean* periods: fo that the irregularities of " their circuits muft undergo new computations " to affign them exactly.

" Nor do all Eclipfes come in at the fouth Pole: " *that* depends altogether on the pofition of the " lunar Nodes, which will bring in as many from " the *expanfum* one way as the other: and fuch " Eclipfes will wear more foutherly by degrees " contrary to what happens in the prefent cafe.

" The Eclipfe, for example, of 1736, in *Sep-* " *tember*, had its center in the *expanfum* and fet " about the middle of its obfcurity in *Britain*: it " will wear in at the North Pole, and in the year " 2600, or thereabout, go off in the *expanfum* on " the fouth fide of the Earth.

" The Eclipfes therefore which happened about " the Creation are little more than half way yet " of their ethereal circuit; and will be 4000 years " before they enter the Earth any more. This " grand revolution feems to have been entirely " unknown to the ancients.

Why our prefent Tables agree not with ancient obfervations.

322. "It is particularly to be noted, that Eclipfes " which have happened many centuries ago, will " not be found by our prefent Tables to agree ex- " actly with ancient obfervations, by reafon of " the great Anomalies in the lunar motions; which " appears an inconteftible demonftration of the " non-eternity of the Univerfe. For it feems con- " firmed by undeniable proofs, that the Moon now " finifhes her period in lefs time than formerly,

 " and

" and will continue by the centripetal law to ap-
" proach nearer and nearer the Earth, and to go
" ſooner and ſooner round it: nor will the centri-
" fugal power be ſufficient to compenſate the dif-
" ferent gravitations of ſuch an aſſemblage of bo-
" dies as conſtitute the ſolar ſyſtem, which would
" come to ruin of itſelf, without ſome new regula-
" tion and adjuſtment of their original motions*.

324. " We are credibly informed from the teſti- THALES's Eclipſe.
" mony of the ancients, that there was a total
" Eclipſe of the Sun predicted by THALES to hap-
" pen in the fourth year of the 48th † *Olympiad*,
" either

* There are two ancient Eclipſes of the Moon, recorded by *Ptolemy* from *Hipparchus*, which afford an undeniable proof of the Moon's acceleration. The firſt of theſe was obſerved at *Babylon*, *December* the 22d, in the year before CHRIST 383: when the Moon began to be eclipſed about half an hour before the Sun roſe, and the Eclipſe was not over before the Moon ſet: but by moſt of our Aſtronomical Tables, the Moon was ſet at *Babylon* half an hour before the Eclipſe began; in which caſe, there could have been no poſſibility of obſerving it. The ſecond Eclipſe was obſerved at *Alexandria*, *September* the 22d, the year before CHRIST 201: where the Moon roſe ſo much eclipſed, that the Eclipſe muſt have begun about half an hour before ſhe roſe: whereas, by moſt of our Tables, the beginning of this Eclipſe was not till about ten minutes after the Moon roſe at *Alexandria*. Had theſe Eclipſes begun and ended while the Sun was below the Horizon, we might have imagined, that as the ancients had no certain way of meaſuring time, they might have been ſo far miſtaken in the hours, that we could not have laid any ſtreſs on the accounts given by them. But, as in the firſt Eclipſe the Moon was ſet, and conſequently the Sun riſen, before it was over; and in the ſecond Eclipſe the Sun was ſet, and the Moon not riſen, till ſometime after it began: theſe are ſuch circumſtances as the obſervers could not poſſibly be miſtaken in. Mr. *Struyk*, in the following Catalogue, notwithſtanding the expreſs words of *Ptolemy*, puts down theſe two Eclipſes as obſerved at *Athens*; where they might have been ſeen as above, without any acceleration of the Moon's motion: *Athens* being 20 degrees Weſt of *Babylon*, and 7 degrees Weſt of *Alexandria*.

† Each *Olympiad* began at the time of Full Moon next after the Summer Solſtice, and laſted four years, which were of unequal lengths, becauſe the time of Full Moon differs 11 days every year: ſo that they might ſometimes begin on the next day

"either at *Sardis* or *Miletus* in *Asia*, where THALES "then resided. That year corresponds to the "585th year before Christ; when accordingly "there happened a very signal eclipse of the Sun, "on the 28th of *May*, answering to the present "10th of that month *, central through *North* "*America*, the South parts of *France*, *Italy*, &c. as "far as *Athens*, or the Isles in the *Ægean* Sea; "which is the farthest that even the *Caroline* Tables "carry it; and consequently make it invisible to "any part of *Asia*, in the total character; though "I have good reasons to believe that it extended "to *Babylon*, and went down central over that city. "We are not however to imagine, that it was set

day after the Solstice, and at other times not till four weeks after it. The first *Olympiad* began in the year of the Julian Period 3938, which was 776 years before the first year of CHRIST, or 775 before the year of his birth; and the last *Olympiad*, which was the 293d, began *A. D.* 393. At the expiration of each *Olympiad*, the *Olympic Games* were celebrated in the *Elean* fields, near the river *Alpheus* in the *Peloponnesus* (now *Morea*) in honour of JUPITER OLYMPUS. See STRAUCHIUS's *Breviarium Chronologicum*, p. 247—251.

* The reader may probably find it difficult to understand why Mr. SMITH should reckon this Eclipse to have been in the 4th year of the 48th *Olympiad*, as it was only in the end of the third year: and also why the 28th of *May*, in the 585th year before CHRIST, should answer to the present 10th of that month. But we hope the following explanation will remove these difficulties.

The month of *May* (when the Sun was eclipsed) in the 585th year before the first year of CHRIST, which was a leap-year, fell in the latter end of the third year of the 48th *Olympiad*; and the fourth year of that *Olympiad* began at the Summer Solstice following: but perhaps Mr. SMITH begins the year of the *Olympiad* from *January*, in order to make them correspond more readily with *Julian* Years; and so reckons the month of *May*, when the Eclipse happened, to be in the fourth year of that *Olympiad*.

The Place or Longitude of the Sun at that time was ♉ 29° 43′ 17″, to which same place the Sun returned (after 2300 years, *viz.*) *A. D.* 1716, on *May* $9^d\ 5^h\ 6^m$ after noon: so that, with respect to the Sun's place, the 9th of *May* 1716, answers to the 28th of *May* in the 585th year before the first year of CHRIST; that is, the Sun had the same Longitude on both those days.

"before

"before it passed *Sardis* and the *Asiatic* towns, "where the predictor lived; because an invisible "Eclipse could have been of no service to demon- "strate his ability in Astronomical Sciences to his "countrymen, as it could give no proof of its reality.

324. "For a further illustration THUCYDIDES "relates that a solar Eclipse happened on a Sum- "mer's day in the afternoon, in the first year of "the *Peloponnesian* war, so great, that the Stars ap- "peared. RHODIUS was victor in the *Olympic* "games the fourth year of the said war, being also "the fourth of the 87th *Olympiad*, on the 428th "year before CHRIST. So that the Eclipse must "have happened in the 431st year before CHRIST; "and by computation it appears, that on the 3d "of *August* there was a signal Eclipse which would "have passed over *Athens*, central about 6 in the "evening, but which our present Tables bring no "farther than the ancient *Syrtes* on the *African* "coast, above 400 miles from *Athens*; which "suffering in that case but 9 Digits, could by no "means exhibit the remarkable darkness recited "by this historian; the center therefore seems to "have passed *Athens* about 6 in the evening, and "probably might go down about *Jerusalem*, or "near it, contrary to the construction of the pre- "sent Tables. I have only obviated these things "by way of caution to the present Astronomers, "in re-computing ancient Eclipses; and refer them "to examine the Eclipse of *Nicias*, so fatal to the "*Athenian* fleet *; that which overthrew the *Ma-* "*cedonian* Army †, *&c.*" So far Mr. SMITH. THUCYDIDES's Eclipse.

325. In any year, the number of Eclipses of both Luminaries cannot be less than two, nor more than seven; the most usual number is four, and it is very rare to have more than six. For the Sun passes by both the Nodes but once a year, unless The number of Eclipses.

* Before CHRIST 413, *August* 27.
† Before CHRIST 168, *June* 21.

he

he passes by one of them in the beginning of the year; and if he does, he will pass by the same Node again a little before the year be finished; because as these points move 19⅓ degrees backward every year, the Sun will come to either of them 173 days after the other, § 319. And when either Node is within 17 degrees of the Sun at the time of New Moon, the Sun will be eclipsed. At the subsequent opposition, the Moon will be eclipsed in the other Node; and come round to the next conjunction again ere the former Node be 17 degrees past the Sun, and will therefore eclipse him again. When three Eclipses fall about either Node, the like number generally falls about the opposite; as the Sun comes to it in 173 days afterward; and six Lunations contain but four days more. Thus there may be two Eclipses of the Sun and one of the Moon about each of her Nodes. But when the Moon changes in either of the Nodes, she cannot be near enough the other Node at the next Full to be eclipsed; and in six lunar months afterward she will change near the other Node: in these cases there can be but two Eclipses in a year, and they are both of the Sun.

326. A longer period than the above mentioned, § 320, for comparing and examining Eclipses which happened at long intervals of time, is 557 years 21 days 18 hours 30 minutes 11 seconds, in which time there are 6890 mean Lunations: and the Sun and Node meet again so nearly as to be but 11 seconds distant; but then it is not the same Eclipse that returns, as in the shorter period above mentioned.

327. We shall subjoin a catalogue of Eclipses recorded in history, from 721 years before CHRIST to *A. D.* 1485; of computed Eclipses from 1485 to 1700; and of all the Eclipses visible in *Europe* from 1700 to 1800. From the beginning of the Catalogue to *A. D.* 1485, the Eclipses are taken from STRUYK's *Introduction to universal Geography*, as

as that indefatigable author has, with much labour, collected them from *Ptolemy*, *Thucydides*, *Plutarch*, *Calvisius*, *Xenophon*, *Diodorus Siculus*, *Justin*, *Polybius*, *Titus Livius*, *Cicero*, *Lucanus*, *Theophanes*, *Dion Cassius*, and many others. From 1485 to 1700 the Eclipses are taken from *Ricciolus's Almagest:* and from 1700 to 1800 from *L'Art de verifier les Dates.* Those from *Struyk* have all the places mentioned where they were observed: Those from the *French* authors, *viz.* the religious *Benedictines* of the congregation of *St. Maur*, are fitted to the Meridian of *Paris:* And concerning those from *Ricciolus*, that author gives the following account:

An account of the following Catalogue of Eclipses.

"Because it is of great use for fixing the Cycles or Revolutions of Eclipses, to have at hand, without the trouble of calculation, a list of successive Eclipses for many years, computed by authors of *Ephemerides*, although from Tables not perfect in all respects, I shall, for the benefit of Astronomers, give a summary collection of such. The authors I extract from are, an anonymous one who published *Ephemerides* from 1484 to 1506 inclusive: *Jacobus Pflaumen* and *Jo. Stæflerinus*, to the Meridian of *Ulm*, from 1507 to 1534: *Lucas Gauricus*, to the Latitude of 45 degrees, from 1534 to 1551: *Peter Appian*, to the Meridian of *Leysing*, from 1538 to 1578: *Jo. Stæflerus*, to the Meridian of *Tubing*, from 1543 to 1554: *Petrus Pitatus*, to the Meridian of *Venice*, from 1544 to 1556: *Georgius Joachimus Rheticus*, for the year 1551: *Nicholus Simus*, to the Meridian of *Bologna*, from 1552 to 1568: *Michael Mæstlin*, to the Meridian of *Tubing*, from 1557 to 1590: *Jo. Stadius*, to the Meridian of *Antwerp*, from 1554 to 1574: *Jo. Antoninus Maginus*, to the Meridian of *Venice*, from 1581 to 1630: *David Origan*, to the Meridian of *Franckfort* on the *Oder*, from 1595 to 1664: *Andrew Argol*, to the Meridian of *Rome*, from 1630 to 1700: *Franciscus Montebrunus*, to the Meridian of *Bologna*, from 1461 to 1660: Among which, *Stadius*, *Mæstlin*, and *Maginus*,

ginus, used the *Prutenic* Tables; *Origin* the *Prutenic* and *Tychonic*; *Montebrunus* the *Lansbergian*, as likewise those of *Durat*. Almost all the rest the *Alphonsine*.

But that the places may readily be known for which these Eclipses were computed, and from what Tables, consult the following List, in which the years *inclusive* are also set down.

From	To	
1485	1506	The place and author unknown.
1507	1553	*Ulm* in *Suabia*, from the *Alphonsine*.
1554	1576	*Antwerp*, from the *Prutenic*.
1577	1585	*Tubing*, from the *Prutenic*.
1586	1594	*Venice*, from the *Prutenic*.
1595	1600	*Franckfort* on the *Oder*, from the *Prutenic*.
1601	1640	*Franckfort* on the *Oder*, from the *Tychonic*.
1641	1660	*Bologna*, from the *Lansbergian*.
1661	1700	*Rome*, from the *Tychonic*."

So far RICCIOLUS.

N. B. The Eclipses marked with an Asterisk are not in RICCIOLUS's Catalogue, but are supplied from *L'Art de verifier les Dates*.

From the beginning of the Catalogue to *A. D.* 1700, the time is reckoned from the noon of the day mentioned to the noon of the following day: but from 1700 to 1800 the time is set down according to our common way of reckoning. Those marked *Pekin* and *Canton* are Eclipses from the *Chinese* chronology according to STRUYK; and throughout the Table this mark ☉ signifies *Sun*, and this ☽ *Moon*.

STRUYK's

Struyk's Catalogue of ECLIPSES.

Bef. Chr.	Eclipses of the Sun and Moon seen at		M. & D.	Middle H. M.	Digits eclipsed
721	Babylon	☽	March 19	10 34	Total
720	Babylon	☽	March 8	11 56	1 5
720	Babylon	☽	Sept. 1	10 18	5 4
621	Babylon	☽	April 21	18 22	2 30
523	Babylon	☽	July 16	12 47	7 24
502	Babylon	☽	Nov. 19	12 21	1 52
49	Babylon	☽	April 25	12 12	1 44
431	Athens	☉	Aug. 3	6 35	11 0
425	Athens	☽	Oct. 9	6 45	Total
424	Athens	☉	March 20	20 17	9 0
413	Athens	☽	Aug. 27	10 15	Total
406	Athens	☽	April 15	8 50	Total
404	Athens	☉	Sept. 2	21 12	8 40
403	Pekin	☉	Aug. 28	5 53	10 40
394	Gnide	☉	Aug. 13	22 17	11 0
383	Athens	☽	Dec. 22	19 6	2 1
382	Athens	☽	June 18	8 54	6 15
382	Athens	☽	Dec. 12	10 21	Total
364	Thebes	☉	July 12	23 51	6 10
357	Syracuse	☉	Feb. 28	22 —	3 33
357	Zant	☽	Aug. 29	7 29	4 21
340	Zant	☉	Sept. 14	18 —	9 0
331	Arbela	☽	Sept. 20	10 9	Total
310	Sicily Island	☉	Aug. 14	20 5	10 22
219	Mysia	☽	March 19	14 5	Total
218	Pergamos	☽	Sept. 1	rising	Total
217	Sardinia	☉	Feb. 11	1 57	9 6
203	Frusini	☉	May 6	2 52	5 40
202	Cumis	☉	Oct. 18	22 24	1 0
201	Athens	☽	Sept. 22	7 14	8 58
200	Athens	☽	March 19	13 9	Total
200	Athens	☽	Sept. 11	14 48	Total
198	Rome	☉	Aug. 6	—	—
190	Rome	☉	March 13	18 —	11 0
188	Rome	☉	July 16	20 38	10 48
174	Athens	☽	April 30	14 33	7 1
168	Macedonia	☽	June 21	8 2	Total
141	Rhodes	☽	Jan. 27	10 8	3 26
104	Rome	☉	July 18	22 0	11 52
63	Rome	☽	Oct. 27	6 22	Total
60	Gibraltar	☉	March 16	setting	Central
54	Canton	☉	May 9	3 41	Total
51	Rome	☉	March 7	2 12	9 0
48	Rome	☽	Jan. 18	10 0	Total
45	Rome	☽	Nov. 6	14 —	Total
36	Rome	☉	May 19	3 52	6 47

STRUYK's Catalogue of ECLIPSES.

Bef Chr.	Eclipses of the Sun and Moon seen at		M. & D.		Middle H. M.		Digits eclipsed	
31	Rome	☉	Aug.	20	setting		Gr. Ecl.	
29	Canton	☉	Jan.	5	4	2	11	0
28	Pekin	☉	June	18	23	48	Total	
26	Canton	☉	Oct.	23	4	16	11	15
24	Pekin	☉	April	7	4	11	2	0
16	Pekin	☉	Nov.	1	5	13	2	8
2	Canton	☉	Feb.	1	20	[illegible]	11	42
Aft. Chr.								
1	Pekin	☉	June	10	1	10	11	43
5	Rome	☉	March	28	4	13	4	45
14	Panonia	☽	Sept.	2'	17	1[illegible]	Total	
27	Canton	☉	July	22	8	56	Total	
30	Canton	☉	Nov.	13	19	20	10	30
40	Pekin	☉	April	30	5	50	7	34
45	Rome	☉	July	31	22	1	5	17
46	Pekin	☉	July	21	22	25	2	10
46	Rome	☽	Dec.	31	9	52	Total	
49	Pekin	☉	May	20	7	16	10	8
53	Canton	☉	March	8	20	42	11	6
55	Pekin	☉	July	12	21	50	6	40
56	Canton	☉	Dec.	25	0	28	9	20
59	Rome	☉	April	30	3	8	10	38
60	Canton	☉	Oct.	13	3	31	10	30
65	Canton	☉	Dec.	15	21	50	10	23
69	Rome	☽	Oct.	18	10	43	10	49
70	Canton	☉	Sept.	22	21	13	8	26
71	Rome	☽	March	4	8	32	6	0
95	Ephesus	☉	May	21	——		1	0
125	Alexandria	☽	April	5	9	16	1	44
133	Alexandria	☽	May	6	11	44	Total	
134	Alexandria	☽	Oct.	20	11	5	10	19
136	Alexandria	☽	March	5	15	56	5	17
237	Bologna	☉	April	12	——		Total	
238	Rome	☉	April	1	20	20	8	45
290	Carthage	☉	May	15	3	20	11	20
304	Rome	☽	Aug.	31	9	36	Total	
316	Constantinople	☉	Dec.	30	19	53	2	18
334	Toledo	☉	July	17	at noon		Central	
348	Constantinople	☉	Oct.	8	19	24	8	0
360	Ispahan	☉	Aug.	27	18	0	Central	
364	Alexandria	☽	Nov.	25	15	24	Total	
401	Rome	☽	June	11	——		Total	
401	Rome	☽	Dec.	6	12	15	Total	
402	Rome	☽	June	1	8	43	10	2

STRUYK's Catalogue of ECLIPSES.

Aft. Chr.	Eclipses of the Sun and Moon seen at		M. & D.		Middle H.	M.	Digits eclipsed	
402	Rome	☉	Nov.	10	20	33	10	30
447	Compostello	☉	Dec.	23	0	46	1	—
451	Compostello	☽	April	1	16	34	19	52
451	Compostello	☽	Sept.	26	6	30	0	2
458	Chaves	☉	May	27	23	16	18	53
462	Compostello	☽	March	1	13	2	11	11
464	Chaves	☉	July	19	19	1	10	15
484	Constantinople	☉	Jan.	13	19	53	10	0
486	Constantinople	☉	May	19	1	10	5	15
497	Constantinople	☉	April	18	6	5	17	57
512	Constantinople	☉	June	28	23	8	1	50
538	England	☉	Feb.	14	19	—	8	23
540	London	☉	June	19	20	15	8	—
577	Tours	☽	Dec.	10	17	28	6	46
581	Paris	☽	April	4	13	33	6	42
582	Paris	☽	Sept.	17	12	41	Total	
590	Paris	☽	Oct.	18	6	30	9	25
592	Constantinople	☉	March	18	22	6	10	0
603	Paris	☉	Aug.	12	3	3	11	20
622	Constantinople	☽	Feb.	1	11	28	Total	
644	Paris	☉	Nov.	5	0	30	9	53
680	Paris	☽	June	17	12	30	Total	
683	Paris	☽	April	16	11	30	Total	
693	Constantinople	☉	Oct.	4	23	54	11	54
716	Constantinople	☽	Jan.	13	7	—	Total	
718	Constantinople	☉	June	3	1	15	Total	
733	England	☉	Aug.	13	20	—	11	1
734	England	☽	Jan.	23	14	—	Total	
752	England	☽	July	30	13	—	Total	
753	England	☉	June	8	22	—	10	35
753	England	☽	Jan.	23	13	—	Total	
760	England	☉	Aug.	15	4	—	8	15
760	London	☽	Aug.	30	5	50	10	40
764	England	☉	June	4	at noon		7	15
770	London	☽	Feb.	14	7	12	Total	
774	Rome	☽	Nov.	22	14	37	11	58
784	London	☽	Nov.	1	14	2	Total	
787	Constantinople	☉	Sept.	14	20	43	9	47
796	Constantinople	☽	March	27	16	22	Total	
800	Rome	☽	Jan.	15	9	0	10	17
807	Angoulesme	☉	Feb.	10	21	24	9	42
807	Paris	☽	Feb.	25	13	43	Total	
807	Paris	☽	Aug.	21	10	20	Total	
809	Paris	☉	July	15	21	33	8	8
809	Paris	☽	Dec.	25	8	—	Total	
810	Paris	☽	June	20	8	—	Total	

Struyk's Catalogue of ECLIPSES.

Aft. Chr.	Eclipses of the Sun and Moon seen at		M. & D.	Middle H. M.	Digits eclipsed
810	Paris	☉	Nov. 30	0 12	Total
810	Paris	☽	Dec. 14	8 —	Total
812	Constantinople	☉	May 14	2 13	9 —
813	Cappadocia	☉	May 3	17 5	10 35
817	Paris	☽	Feb. 5	5 42	Total
818	Paris	☉	July 6	18 —	6 35
820	Paris	☽	Nov. 23	6 26	Total
824	Paris	☽	March 18	7 55	Total
828	Paris	☽	June 30	15 —	Total
828	Paris	☽	Dec. 24	13 45	Total
831	Paris	☽	April 30	6 19	11 8
831	Paris	☉	May 15	23 —	4 24
831	Paris	☽	Oct. 24	11 18	Total
832	Paris	☽	April 18	9 0	Total
840	Paris	☉	May 4	23 22	9 20
841	Paris	☉	Oct. 17	18 58	5 24
842	Paris	☽	March 29	14 38	Total
843	Paris	☽	March 19	7 1	Total
861	Paris	☽	March 29	15 7	Total
878	Paris	☽	Oct. 14	16 —	Total
878	Paris	☉	Oct. 29	1 —	11 14
883	Arracta	☽	July 23	7 44	11 —
889	Constantinople	☉	April 3	17 52	9 23
891	Constantinople	☉	Aug. 7	23 48	10 30
901	Arracta	☽	Aug. 2	15 7	Total
904	London	☽	May 31	11 47	Total
904	London	☽	Nov. 25	9 0	Total
912	London	☽	Jan. 6	15 12	Total
926	Paris	☽	March 31	15 17	Total
934	Paris	☉	April 16	4 30	11 36
939	Paris	☉	July 18	19 45	10 7
955	Paris	☽	Sept. 4	11 18	Total
961	Rhemes	☉	May 16	20 13	9 18
970	Constantinople	☉	May 7	18 38	11 22
976	London	☽	July 13	15 7	Total
985	Messina	☉	July 20	3 52	4 10
989	Constantinople	☉	May 28	6 54	8 40
990	Fulda	☽	April 12	10 22	9 5
990	Fulda	☽	Oct. 6	15 4	1 10
990	Constantinople	☉	Oct. 21	0 45	10 5
995	Augsburgh	☽	July 14	11 27	Total
1009	Ferrara	☽	Oct. 6	11 38	Total
1010	Messina	☽	March 18	5 41	9 12
1016	Nimeguen	☉	Nov. 16	16 39	Total
1017	Nimeguen	☉	Oct. 22	2 8	6 —
1020	Cologne	☽	Sept. 4	11 38	Total

Struyk's Catalogue of ECLIPSES.

Aft. Chr.	Eclipses of the Sun and Moon seen at		M. & D.		Middle H.	M.	Digits eclipsed	
1023	London	☉	Jan.	23	23	29	11	—
1030	Rome	☽	Feb.	20	11	43	Total	
1031	Paris	☽	Feb.	9	11	51.	Total	
1033	Paris	☽	Dec.	8	11	11	9	17
1034	Milan	☽	June	4	9	8	Total	
1037	Paris	☉	April	17	20	45	10	45
1039	Auxerre	☉	Aug.	21	23	40	11	5
1042	Rome	☽	Jan.	8	16	39	Total	
1044	Auxerre	☽	Nov.	7	16	12	10	1
1044	Cluny	☉	Nov.	21	22	12	11	—
1056	Nuremburg	☽	April	2	12	9	Total	
1063	Rome	☽	Nov.	8	12	16	Total	
1074	Augſburgh	☽	Oct.	7	10	13	Total	
1080	Conſtantinople	☽	Nov.	29	11	12	9	36
1082	London	☽	May	14	10	32	10	2
1086	Conſtantinople	☉	Feb.	16	4	7	Total	
1089	Naples	☽	June	25	6	6	Total	
1093	Augſburgh	☉	Sept.	22	22	35	10	12
1096	Gembluors	☽	Feb.	10	16	4	Total	
1096	Augſburgh	☽	Aug.	6	8	21	Total	
1098	Augſburgh	☉	Dec.	25	1	25	0	12
1099	Naples	☽	Nov.	30	4	58	Total	
1103	Rome	☽	Sept.	17	10	18	Total	
1106	Erfurd	☽	July	17	11	28	11	54
1107	Naples	☽	Jan.	10	13	16	Total	
1109	Erfurd	☉	May	31	1	30	10	20
1110	London	☽	May	5	10	51	Total	
1113	Jeruſalem	☉	March	18	19	0	9	12
1114	London	☽	Aug.	17	15	5	Total	
1117	Triers	☽	June	15	13	26	Total	
1117	Triers	☽	Dec.	10	12	51	Total	
1120	Naples	☽	Nov.	29	15	46	4	11
1121	Triers	☽	Sept.	27	16	87	Total	
1122	Prague	☽	March	24	11	20	3	49
1124	Erfurd	☽	Feb.	1	6	43	8	39
1124	London	☉	Aug.	10	23	29	9	58
1132	Erfurd	☽	March	3	8	14	Total	
1133	Prague	☽	Feb.	20	16	41	3	23
1135	London	☽	Dec.	22	20	11	Total	
1142	Rome	☽	Feb.	11	14	17	8	30
1143	Rome	☽	Feb.	1	6	36	Total	
1147	Auranches	☉	Oct.	25	22	38	7	20
1149	Bary	☽	March	25	13	54	5	29
1151	Eimbeck	☽	Aug.	28	12	4	4	29
1153	Augſburgh	☉	Jan.	26	0	42	11	—
1154	Paris	☽	June	26	16	1	Total	

Struyk's Catalogue of ECLIPSES.

Aft. Chr.	Eclipses of the Sun and Moon seen at		M. & D.		Middle H.	M.	Digits eclipsed	
1154	Paris	☽	Dec.	21	8	30	4	22
1155	Auranches	☽	June	16	8	45	0	53
1160	Rome	☽	Aug.	18	7	53	6	49
1161	Rome	☽	Aug.	7	8	11	Total	
1162	Erfurd	☽	Feb.	1	6	40	5	56
1162	Erfurd	☽	July	27	12	30	4	11
1163	Mont Cassin	☉	July	3	7	40	2	0
1164	Milan	☽	June	6	10	0	Total	
1168	London	☽	Sept.	18	14	0	Total	
1172	Cologne	☽	Jan.	11	13	31	Total	
1176	Auranches	☽	April	25	7	2	8	6
1176	Auranches	☽	Oct.	19	11	20	8	53
1178	Cologne	☽	March	5	setting		7	52
1178	Auranches	☽	Aug.	29	13	52	5	31
1178	Cologne	☉	Sept.	12	—		10	51
1179	Cologne	☽	Aug.	18	14	28	Total	
1180	Auranches	☉	Jan.	28	4	14	10	34
1181	Auranches	☉	July	13	3	15	3	48
1181	Auranches	☽	Dec.	22	8	58	4	40
1185	Rhemes	☉	May	1	1	53	9	0
1186	Cologne	☽	April	5	6	—	Total	
1186	Franckfort	☉	April	20	7	19	4	0
1187	Paris	☽	March	25	16	17	8	42
1187	England	☉	Sept.	3	21	54	8	6
1189	England	☽	Feb.	2	10	—	9	—
1191	England	☉	June	23	0	20	11	32
1192	France	☽	Nov.	20	14	—	6	—
1193	France	☽	Nov.	10	5	27	Total	
1194	London	☉	April	22	2	15	6	49
1200	London	☽	Jan.	2	17	2	4	35
1201	London	☽	June	17	15	4	Total	
1204	England	☽	April	15	12	39	Total	
1204	Saltsburg	☽	Oct.	10	6	32	Total	
1207	Rhemes	☉	Feb.	27	10	50	10	20
1208	Rhemes	☽	Feb.	2	5	10	Total	
1211	Vienna	☽	Nov.	21	13	57	Total	
1215	Cologne	☽	March	16	15	35	Total	
1216	Acre	☉	Feb.	18	21	15	11	36
1216	Acre	☽	March	5	9	28	7	4
1218	Damiétta	☽	July	9	9	46	11	31
1222	Rome	☽	Oct.	22	14	28	Total	
1223	Colmar	☽	April	16	8	13	11	0
1228	Naples	☉	Dec.	27	9	55	9	19
1230	Naples	☉	May	13	17	—	Total	
1230	London	☽	Nov.	21	13	21	9	34
1232	Rhemes	☉	Oct.	15	4	29	4	25

STRUYK's Catalogue of ECLIPSES.

Aft. Chr.	Eclipſes of the Sun and Moon ſeen at		M. & D.		Middle H.	M.	Digits eclipſed	
1245	Rhemes	☉	July	24	17	47	6	—
1248	London	☽	June	7	8	49	Total	
1255	London	☽	July	20	9	47	Total	
1255	Conſtantinople	☉	Dec.	30	2	52	Annul	
1258	Augſburgh	☽	May	18	11	17	Total	
1261	Vienna	☉	March	31	22	40	9	8
1262	Vienna	☽	March	7	5	50	Total	
1262	Vienna	☽	Aug.	30	14	39	Total	
1263	Vienna	☽	Feb.	24	6	52	6	29
1263	Augſburgh	☉	Aug.	5	3	24	11	17
1263	Vienna	☽	Aug.	20	7	35	9	7
1265	Vienna	☽	Dec.	23	16	25	Total	
1267	Conſtantinople	☉	May	24	23	11	11	40
1270	Vienna	☉	March	22	18	47	10	40
1272	Vienna	☽	Aug.	10	7	27	8	53
1274	Vienna	☽	Jan.	23	10	39	9	25
1275	Lauben	☽	Dec.	4	6	20	4	29
1276	Vienna	☽	Nov.	22	15	—	Total	
1277	Vienna	☽	May	18	—	—	Total	
1279	Franckfort	☉	April	12	6	55	10	6
1280	London	☽	March	17	12	12	Total	
1284	Reggio	☽	Dec.	23	16	11	9	13
1290	Wittemburg	☉	Sept.	5	19	37	10	30
1291	London	☽	Feb.	14	10	2	Total	
1302	Conſtantinople	☽	Jan.	14	10	25	Total	
1307	Ferrara	☉	April	2	22	18	0	54
1309	London	☽	Feb.	24	17	44	Total	
1309	Lucca	☽	Aug.	21	10	32	Total	
1310	Wittemburg	☉	Jan.	31	2	2	10	19
1310	Torcello	☽	Feb.	14	4	8	10	20
1310	Torcello	☽	Aug.	10	15	33	7	16
1312	Wittemburg	☉	July	4	19	49	3	23
1312	Plaiſance	☽	Dec.	14	7	19	Total	
1313	Torcello	☽	Dec.	3	8	58	9	34
1316	Modena	☽	Oct.	1	14	55	Total	
1321	Wittemburg	☉	June	25	18	1	11	17
1323	Florence	☽	May	20	15	24	Total	
1324	Florence	☽	May	9	6	3	Total	
1324	Wittemburg	☉	April	23	6	35	8	8
1327	Conſtantinople	☽	Aug.	31	18	26	Total	
1328	Conſtantinople	☽	Feb.	25	13	47	11	—
1330	Florence	☽	June	30	15	10	7	34
1330	Conſtantinople	☉	July	16	4	5	10	43
1330	Prague	☽	Dec.	25	15	49	Total	
1331	Prague	☉	Nov.	29	20	26	7	41
1331	Prague	☽	Dec.	14	18	—	11	—

STRUYK's Catalogue of ECLIPSES.

Ant. Chr.	Eclipses of the Sun and Moon seen at		M. & D.	Middle H. M.	Digits eclipsed
1333	Wittemburg	☉	May 14	3 —	10 18
1334	Cesena	☽	April 19	10 33	Total
1341	Constantinople	☽	Nov. 23	12 23	Total
1341	Constantinople	☉	Dec. 8	22 15	6 30
1342	Constantinople	☽	May 20	14 27	Total
1344	Alexandria	☉	Oct. 6	18 40	8 55
1349	Wittemburg	☽	June 30	12 20	Total
1354	Wittemburg	☉	Sept. 16	20 45	8 43
1356	Florence	☽	Feb. 16	11 43	Total
1361	Constantinople	☉	May 4	22 15	8 54
1367	Sienna	☽	Jan. 16	8 27	Total
1389	Ergibio	☽	Nov. 3	17 5	Total
1396	Augsburgh	☉	Jan. 11	0 16	6 22
1396	Augsburgh	☽	June 21	11 10	Total
1399	Forli	☉	Oct. 29	0 43	9 —
1406	Constantinople	☽	June 1	13 —	10 31
1406	Constantinople	☉	June 15	18 1	11 38
1408	Forli	☉	Oct. 18	21 47	9 32
1409	Constantinople	☉	April 15	3 1	10 48
1410	Vienna	☽	March 20	13 13	Total
1415	Wittemburg	☉	June 6	6 43	Total
1419	Franckfort	☉	March 25	22 5	1 45
1421	Forli	☽	Feb. 17	8 2	Total
1422	Forli	☽	Feb. 6	8 26	11 7
1424	Wittemburg	☉	June 26	3 57	11 20
1431	Forli	☉	Feb. 12	2 4	1 39
1433	Wittemburg	☉	June 17	5 —	Total
1438	Wittemburg	☉	Sept. 18	20 59	8 7
1442	Rome	☽	Dec. 17	3 59	Total
1448	Tubing	☉	Aug. 28	22 23	8 53
1450	Constantinople	☽	July 24	7 19	Total
1457	Vienna	☽	Sept. 3	11 17	Total
1460	Austria	☽	July 3	7 31	5 23
1460	Austria	☉	July 17	17 32	11 19
1460	Vienna	☽	Dec. 27	13 30	Total
1461	Vienna	☽	June 22	11 50	Total
1461	Rome	☽	Dec. 17	———	Total
1462	Viterbo	☽	June 11	15 —	7 38
1462	Viterbo	☉	Nov. 21	0 10	2 6
1464	Padua	☽	April 21	12 43	Total
1465	Rome	☉	Sept. 20	5 15	8 46
1465	Rome	☽	Oct. 4	5 12	Total
1469	Rome	☽	Jan. 27	7 9	Total
1485	Nurimburg	☉	March 16	3 53	11 —

All the following ECLIPSES are taken from RICCIOLUS, except those marked with an Asterisk, which are from *L'Art de verifier les Dates.*

Aft. Chr		M. & D.	Middle H.	M.	Digits eclipsed	Aft. Chr.		M. & D.	Middle H.	M.	Digits eclipsed
1486	☽	Feb. 18	5	41	Total	1508	☉	May 29	6	—	*
1486	☉	March 5	17	43	9 0	1508	☽	June 12	17	40	Total
1487	☽	Feb. 7	15	49	Total	1509	☽	June 2	11	11	7 0
1487	☉	July 20	2	6	7 0	1509	☉	Nov. 11	22	—	*
1488	☽	Jan. 28	6	—	*	1510	☽	Oct. 16	19	—	*
1488	☉	July 8	17	30	4 0	1511	☽	Oct. 6	11	50	Total
1489	☽	Dec. 7	17	41	Total	1512	☽	Sept. 25	3	56	Total
1490	☉	May 19	Noon		*	1513	☉	March 7	0	30	6 0
1490	☽	June 2	10	6	Total	1513	☉	July 30	1	—	*
1490	☽	Nov. 26	18	25	Total	1515	☽	Jan. 29	15	18	Total
1491	☉	March 8	2	19	9	1516	☽	Jan. 19	6	0	Total
1491	☽	Nov. 15	18	—	*	1516	☽	July 13	11	37	Total
1492	☉	April 26	7	—	*	1516	☉	Dec. 23	3	47	3 0
1492	☉	Oct. 20	23	—	*	1517	☉	June 18	16	—	*
1493	☽	April 1	14	0	Total	1517	☽	Nov. 27	19	—	*
1493	☉	Oct. 10	2	40	8 0	1518	☽	May 24	11	19	9 11
1494	☉	March 7	4	12	4 0	1518	☉	June 7	17	56	11 0
1494	☽	March 21	14	38	Total	1519	☉	May 28	1	—	*
1494	☽	Sept. 14	19	45	Total	1519	☉	Oct. 23	4	33	6 0
1495	☽	March 10	16	—	*	1519	☽	Nov. 6	6	24	Total
1495	☉	Aug. 19	17	—	*	1520	☽	May 2	7	—	*
1496	☽	Jan. 29	14	—	*	1520	☉	Oct. 11	5	22	3
1497	☽	Jan. 18	6	38	Total	1520	☽	Oct. 25	19	—	*
1497	☉	July 29	3	2	3 0	1520	☽	March 21	17	—	*
1499	☽	June 22	17	—	*	1521	☉	April 6	19	—	*
1499	☉	Aug. 23	18	—	*	1521	☉	Sept. 30	3	—	*
1499	☽	Nov. 17	10	—	*	1522	☽	Sept. 5	12	17	Total
1500	☉	March 27	In	the	Night	1523	☽	March 1	8	26	Total
1500	☽	April 11		At	Noon	1523	☽	Aug. 25	15	24	Total
1500	☽	Oct. 5	14	2	10 0	1524	☉	Feb. 4	1	—	*
1501	☽	May 2	17	49	Total	1524	☽	Aug. 16	16	—	*
1502	☉	Sept. 30	19	45	10 0	1525	☉	Jan. 23	4	—	*
1502	☽	Oct. 15	12	20	2 0	1525	☽	July 4	10	10	Total
1503	☽	March 12	9	—	*	1525	☽	Dec. 29	10	46	Total
1503	☉	Sept. 19	22	—	*	1526	☽	Dec. 18	10	30	Total
1504	☽	Feb. 29	13	36	Total	1527	☉	Jan. 2	3	—	*
1504	☉	March 16	3	—	*	1527	☽	Dec. 7	10	—	*
1505	☽	Aug. 14	8	18	Total	1528	☉	May 17	20	—	*
1506	☽	Feb. 7	15	—	*	1529	☽	Oct. 16	20	23	11 55
1507	☉	July 20	3	11	2 0	1530	☉	March 28	18	23	8 4
1506	☽	Aug. 3	10	—	*	1530	☽	Oct. 6	12	11	Total
1507	☉	Jan. 12	19	—	*	1531	☽	April 1	7	—	*
1508	☉	Jan. 2	4	—	*	1532	☉	Aug. 30	0	40	3

RICCIOLUS's Catalogue of ECLIPSES.

Aft. Chr.		M. & D.	Middle H. M.	Digits eclipsed	Aft. Chr.		M. & D.	Middle H. M	Digits eclipsed
1533	☽	Aug. 4	11 50	Total	1556	☉	Nov. 1	18 0	9 41
1533	☉	Aug. 19	17 —	*	1556	☽	Nov. 16	12 44	6 55
1534	☉	Jan. 14	1 42	5 45	1557	☉	Oct. 20	20 —	*
1534	☽	Jan. 29	14 25	Total	1558	☽	April 2	11 0	9 50
1535	☉	June 30	Noon	*	1558	☉	April 18	1 —	*
1535	☽	July 17	8 —	*	1559	☽	April 16	4 50	Total
1535	☉	Dec. 24	2 —	*	1560	☽	March 11	15 40	4 13
1536	☉	June 18	2 2	8 0	1560	☉	Aug. 21	1 0	6 22
1536	☽	Nov. 27	6 21	10 15	1560	☽	Sept. 3	7 —	*
1537	☽	May 24	8 3	Total	1561	☉	Feb. 13	29 —	*
1537	☉	June 7	8 —	*	1562	☉	Feb. 3	5 —	*
1537	☽	Nov. 16	14 56	Total	1562	☽	July 15	15 50	Total
1538	☽	May 13	14 24	3 0	1563	☉	Jan. 22	19 —	*
1538	☽	Nov. 6	5 31	3 37	1563	☉	June 20	4 50	8 38
1539	☉	April 8	4 33	9 0	1563	☽	July 5	8 4	11 34
1540	☉	April 6	17 15	Total	1565	☉	March 7	12 53	
1541	☽	March 11	16 34	Total	1565	☽	May 14	16 —	*
1541	☉	Aug. 21	0 56	3	1565	☽	Nov. 7	12 46	11 46
1542	☽	March 1	8 46	1 38	1566	☽	Oct. 28	5 38	Total
1542	☉	Aug. 10	17 —	*	1567	☉	April 8	23 4	6 34
1543	☽	July 15	16 —	*	1567	☽	Oct. 17	13 43	2 40
1544	☽	Jan. 9	18 13	Total	1568	☉	March 28	5 —	*
1544	☉	Jan. 23	21 16	11 17	1569	☽	March 2	15 18	Total
1544	☽	July 4	8 31	Total	1570	☽	Feb. 20	5 46	Total
1544	☽	Dec. 28	18 27	Total	1570	☽	Aug. 15	9 17	Total
1545	☉	June 8	20 48	3 45	1571	☉	Jan. 25	4 —	*
1545	☽	Dec. 17	18 —	*	1572	☉	Jan. 14	19 —	*
1546	☉	May 30	5 —	*	1572	☽	June 25	9 0	5 26
1546	☉	Nov. 22	23 —	*	1573	☉	June 28	18 —	*
1547	☽	May 4	10 27	8 0	1573	☉	Nov. 24	4 —	*
1547	☽	Oct. 28	4 56	11 34	1573	☽	Dec. 8	6 51	Total
1547	☉	Nov. 12	2 9	9 30	1574	☉	Nov. 13	3 50	5 21
1548	☉	April 8	3 —	*	1575	☉	May 19	8 —	6
1548	☽	April 22	11 24	Total	1575	☉	Nov. 2	5 —	*
1549	☽	April 11	15 19	2 0	1576	☽	Oct. 7	9 45	
1549	☽	Oct. 6	6 —	*	1577	☽	April 2	8 33	Total
1550	☉	March 16	20 —	*	1577	☽	Sept. 26	13 4	Total
1551	☽	Feb. 20	8 21	Total	1578	☽	Sept. 15	13 4	2 20
1551	☉	Aug. 31	2 0	1 52	1579	☉	Feb. 15	5 41	8 36
1553	☉	Jan. 12	22 54	1 22	1579	☉	Aug. 20	19 0	*
1553	☉	July 10	7 —	*	1580	☽	Jan. 31	10 7	Total
1553	☽	July 24	16 0	0 31	1581	☽	Jan. 19	9 22	Total
1554	☉	June 29	6 —	*	1581	☽	July 15	17 51	Total
1554	☽	Dec. 8	13 7	10 12	1582	☽	Jan. 8	10 29	0 53
1555	☽	June 4	15 0	Total	1582	☉	June 9	17 5	7 5
1555	☉	Nov. 13	19 —	*	1583	☽	Nov. 28	21 51	Total

Ricciolus's Catalogue of ECLIPSES.

Aft. Chr.		M. & D.	Middle M. H	Digits eclipsed	Aft. Chr.		M. & D.	Middle H. M.	Digits eclipsed
1584	☉	May 9	18 20	3 36	1601	☽	June 15	6 18	4 52
1584	☽	Nov. 17	4 15	Total	1601	☉	June 29	China	4 29
1585	☉	April 29	7 53	11 7	1601	☽	Dec. 9	7 6	10 53
1585	☽	May 13	5 9	6 54	1601	☉	Dec. 24	2 46	9 52
1586	☽	Sept. 27	8 —	*	1602	☉	May 21	Greenl.	2 41
1586	☉	Oct. 12	Noon	*	1602	☽	June 4	7 18	Total
1587	☽	Sept. 16	9 28	10 2	1602	☉	June 19	N.Gra.	5 43
1588	☉	Feb. 26	1 23	1 3	1602	☉	Nov. 13	Magel.	3 —
1588	☽	March 12	14 14	Total	1602	☽	Nov. 28	10 2	Total
1588	☽	Sept. 4	17 30	Total	1603	☉	May 10	China	11 21
1589	☉	Aug. 10	8 —	* —	1603	☽	May 24	11 41	7 59
1589	☽	Aug. 25	8 1	3 45	1603	☉	Nov. 3	Rom.I.	11 17
1590	☉	Feb. 4	5 —	*	1603	☽	Nov. 18	7 31	3 26
1590	☽	July 16	17 4	3 54	1604	☉	April 20	Arabia	9 32
1590	☉	July 30	19 57	10 27	1604	☉	Oct. 22	Peru	6 49
1591	☽	Jan. 9	6 21	9 40	1605	☽	April 3	9 19	11 49
1591	☽	July 6	5 8	Total	1605	☉	April 18	Madag	5 31
1591	☉	July 20	4 2	1 0	1605	☽	Sept. 27	4 27	9 26
1591	☽	Dec. 29	16 11	Total	1605	☉	Oct. 12	2 32	9 24
1592	☽	June 24	10 13	8 58	1606	☉	March 8	Mexico	6 0
1592	☽	Dec. 18	7 24	5 54	1606	☽	March 24	11 17	Total
1593	☉	May 30	2 30	2 38	1606	☉	Sept. 2	Magel	6 40
1594	☉	May 19	14 58	10 23	1606	☉	Sept. 2	Magel.	6 40
1594	☽	Oct. 2	19 15	9 40	1606	☽	Sept. 16	15 6	Total
1595	☉	April 9	Ter. de	Fuego	1607	☉	Feb. 25	21 48	1 13
1595	☽	April 24	4 12	Total	1607	☽	March 13	6 36	1 22
1595	☉	May 7	22 —	*	1607	☉	Sept. 5	15 40	4 7
1595	☉	Oct. 3	2 4	5 18	1608	☉	Feb. 15	at the	Antipo
1595	☽	Oct. 18	20 47	Total	1608	☽	July 27	0 30	1 53
1596	☉	March 28	In	Chili	1608	☉	Aug. 9	4 39	0 40
1596	☽	April 12	8 52	6 4	1609	☽	Jan. 19	15 21	10 32
1596	☉	Sept. 21	In	China	1609	☉	Feb. 4	Fuego	5 22
1596	☽	Oct. 6	21 15	3 33	1609	☽	July 16	12 8	Total
1597	☉	March 16	St Pet.	Isle	1609	☉	July 30	Canada	4 10
1597	☉	Sept. 11	Picora	9 49	1609	☉	Dec. 26	19 —	5 50
1598	☽	Feb. 20	18 12	10 55	1610	☽	Jan. 9	1 31	Total
1598	☉	March 6	22 12	11 57	1610	☉	June 20	Java	10 46
1598	☽	Aug. 16	1 15	Total	1610	☽	July 5	16 58	11 13
1598	☉	Aug. 31	Magel.	8 34	1610	☉	Dec. 15	Cyprus	4 50
1599	☽	Feb. 10	18 21	Total	1610	☽	Dec. 29	16 47	4 23
1599	☉	July 22	4 31	8 18	1611	☉	June 10	Califor	11 30
1599	☽	Aug. 6	———	Total	1612	☽	May 14	10 38	7 22
1600	☉	Jan. 15	Java.	11 48	1612	☉	May 29	23 38	7 1
1600	☽	Jan. 30	6 40	2 58	1612	☽	Nov. 8	3 22	[illegible] 49
1600	☉	July 10	2 10	5 39	1612	☉	Nov. 22	Magel.	9 0
1601	☉	Jan. 4	Ethiop	9 40	1613	☉	April 20	Magel	Ja[illegible]ica

Ricciolus's Catalogue of ECLIPSES.

Aft. Chr.		M. & D.	Middle H. M.	Digits eclipſed	Aft. Chr.		M. & D.	Middle H. M.	Digits eclipſe
1613	.	May 4	0 35	Total	1625	☉	March 8	Florida	
1613	☉	May 19	Eaſt	Tartary	1625	☽	March 23	14 11	2 11
1613	☉	Oct. 13	South	Amer.	1625	☉	Sept. 1	St. Pe	ter'sIſle
1613	☽	Oct. 28	4 19	Total	1625	☽	Sept. 16	11 41	5 6
1614	☉	April 8	N.Gui.	8 44	1626	☉	Feb. 25	Madag.	8 27
1614	☽	April 23	17 36	5 25	1626	☽	Aug. 7	7 48	0 25
1614	☉	Oct. 3	0 57	5 2	1626	☉	Aug. 21	In	Mexico
1614	☽	Oct. 17	4 38	4 56	1627	☽	Jan. 30	11 38	10 21
1615	☉	March 29	Goa	10 38	1627	☉	Feb. 15	Magel	lanica
1615	☉	Sept. 22	Salom	Iſle	1627	☽	July 27	9 4	Total
1615	☽	March 3	1 58	Total	1627	☉	Aug. 11	Tenduc	10 0
1616	☉	March 17	Mexico	6 47	1628	☉	Jan. 6	Tenduc	5 40
1616	☽	Aug. 26	15 33	Total	1628	☽	Jan. 20	10 11	Total
1616	☽	Sept. 10	Magel.	10 33	1628	☉	July 1	CGood	Hope
1617	☉	Feb. 5	Magel	lanica	1628	☽	July 16	11 26	Total
1617	☽	Feb. 20	1 49	Total	1628	☉	Dec. 25	In Eng	land
1617	☉	March 6	22 —		1629	☽	Jan. 9	1 36	4 27
1617	☉	Aug. 1	Biarmia	*	1629	☉	June 11	Gange	11 25
161	☽	Aug. 16	8 22	Total	1629	☉	Dec. 14	Peru	10 14
1618	☉	Jan. 26	Magel	lanica	1630	☽	May 25	17 56	6 0
1618	☽	Feb. 9	3 29	2 57	1630	☉	June 10	7 47	9 8
1618	☉	July 21	Mexico	——	1630	☽	Nov. 19	11 24	9 27
1619	☉	Jan. 15	Califor	nia	1630	☉	Dec. 3	N.Gui.	10 10
1619	☽	June 26	12 40	5 10	1631	☉	April 30	Antar.	Circle
1619	☉	July 11	Africa	11 39	1631	☽	May 15	8 15	Total
1619	☽	Dec. 20	15 53	10 47	1631	☉	Oct. 24	CGood	Hope
1620	☉	May 31	Arctic	Circle	1631	☽	Nov. 8	12 0	Total
1620	☽	June 14	13 47	Total	1632	☉	April 19	CGood	Hope
1620	☉	June 29	Magel.	7 20	1632	☽	May 4	1 24	6 35
1620	☽	Dec. 9	6 39	Total	1632	☉	Oct. 13	Mexico	8 37
1620	☉	Dec. 23	Magel	lanica	1632	☽	Oct. 17	12 23	5 31
1621	☉	May 20	14 54	10 44	1633	☉	April 8	5 14	4 30
1621	☽	June 3	19 42	9 53	1633	☉	Oct. 3	Maldiv.	Total
1621	☉	Nov. 13	Magel	lanica	1634	☽	March 14	9 35	11 18
1621	☽	Nov. 28	15 43	3 28	1634	☉	March 28	Japan	10 19
1622	☉	May 10	C.Ver	11 52	1634	☽	Sept. 7	5 0	Total
1622	☉	Nov. 2	Malac	ca In.	1634	☉	Sept. 22	CG.H.	9 54
1623	☽	April 14	7 19	10 54	1635	☉	Feb. 17	Antar.	Circle
1623	☉	April 29	——	——	1635	☽	March 3	9 26	Total
1623	☽	Oct. 8	0 22	8 35	1635	☉	March 18	Mexico	0 16
1623	☉	Oct. 23	Califor	10 46	1635	☉	Aug. 12	Iceland.	5 0
1624	☉	May 18	N.Zem.	6 0	1635	☽	Aug. 27	16 4	Total
1624	☽	April 3	7 9	Total	1636	☉	Feb. 6	In	Peru
1624	☉	April 17	Antar.	Circle	1636	☽	Feb. 20	11 34	3 23
1624	☉	Sept. 12	Magel	lanica	1636	☉	Aug. 1	Tartary	11 20
1624	☽	Sept. 26	8 55	Total	1636	☽	Aug. 16	4 34	1 25

Ricciolus's Catalogue of ECLIPSES.

Aft. Chr.		M. & D.	Middle H. M.	Digits eclipsed	Aft. Chr.		M. & D.	Middle H. M.	Digits eclipsed
1637	☉	Jan. 26	Cam-	boya	1649	☉	June 9	Arct. C	4 0
1637	☉	July 21	Jucutan		1649	☉	Nov. 4	2 10	3 16
1637	☽	Dec. 31	0 44	10 45	1649	☽	Nov. 18	19 56	Total
1638	☉	Jan. 14	Persia	9 45	1650	☉	April 30	5 54	——
1638	☽	June 25	20 17	Total	1650	☽	May 15	8 37	7 57
1638	☉	July 11	Mag	9 5	1650	☉	Oct. 24	17 17	——
1638	☉	Dec. 5	ellan	2 10	1650	☽	Nov. 7	20 29	5 3
1638	☽	Dec. 20	15 16	Total	1651	☉	April 19	Tuber.	——
1639	☉	Jan. 4	Tartary	0 30	1651	☉	Oct. 14	2 15	——
1639	☉	June 1	5 29	10 40	1652	☽	March 24	16 52	8 50
1639	☽	June 15	2 41	11 9	1652	☉	April 7	22 40	9 59
1639	☉	Nov. 24	Magel.	11 0	1652	☽	Sept. 17	7 27	9 49
1639	☽	Dec. 9	11 57	3 46	1652	☉	Oct. 2	5 2	——
1640	☉	May 20	N.Spa.	10 30	1653	☉	Feb. 27	——	——
1640	☉	Nov. 13	Peru	10 36	1653	☽	March 13	17 9	Total
1641	☽	April 25	1 2	9 49	1653	☉	Aug. 22	——	——
1641	☉	May 9	Peru	10 16	1653	☽	Sept. 6	23 45	Total
1641	☽	Oct. 18	8 19	6 31	1654	☉	Feb. 16	9 10	——
1641	☉	Nov. 2	18 46	——	1654	☽	March 2	19 25	3 14
1642	☉	March 30	Estotl.	4 0	1654	☉	Aug. 11	22 24	2 28
1642	☽	April 14	14 31	Total	1654	☽	Aug. 27	11 40	1 53
1642	☉	Sept. 25	Magel	lanica	1655	☉	Feb. 6	2 37	4 20
1642	☽	Oct. 7	16 45	Total	1655	☉	Aug. 1	14 19	——
1643	☉	March 19	13 53	——	1655	☽	Aug. 16	16 —	*
1643	☽	April 3	21 10	3 9	1656	☽	Jan. 11	9 4	10 0
1643	☉	Sept. 12	17 0	——	1656	☽	July 6	3 17	Total
1643	☽	Sept. 27	7 38	6 0	1656	☉	July 21	11 48	——
1644	☉	March 8	6 20	——	1656	☽	Dec. 30	23 30	Total
1644	☉	Aug. 31	18 10	——	1657	☉	June 11	11 20	——
1645	☽	Feb. 10	7 45	8 52	1657	☽	June 25	9 35	Total
1645	☉	Feb. 26	Rom.I.	10 46	1657	☉	Dec. 4	20 0	——
1645	☽	Aug. 7	2 4	Total	1657	☽	Dec. 20	7 47	3 9
1645	☉	Aug. 21	0 35	4 40	1658	☉	May 31	16 0	——
1646	☉	Jan. 16	Str. of	Anian	1658	☽	June 14	22 58	——
1646	☽	Jan. 30	18 11	Total	1658	☽	Nov. 9	13 56	0 10
1646	☉	July 12	6 57	——	1658	☉	Nov. 24	11 36	——
1646	☽	July 27	6 2	Total	1659	☽	May 6	8 34	8 5
1647	☉	Jan. 5	12 10	——	1659	☉	May 20	17 4	——
1647	☽	Jan. 20	9 43	4 47	1659	☽	Oct. 29	16 16	5 52
1647	☉	July 2	0 9	——	1659	☉	Nov. 14	4 25	9 51
1647	☉	Dec. 25	13 38	——	1660	☽	April 24	11 58	Total
1648	☽	June 5	0 55	4 28	1660	☉	Oct. 3	22 34	——
1648	☉	June 20	13 28	——	1660	☽	Oct. 18	0 32	Total
1648	☽	Nov. 29	19 17	7 40	1660	☉	Nov. 2	13 48	——
1648	☉	Dec. 13	21 48	——	1661	☉	March 29	22 32	——
1649	☽	May 25	15 20	Total	1661	☽	April 14	4 28	——

RICCIOLUS's Catalogue of ECLIPSES.

Aft. Chr.		M. & D.		Middle H.	M.	Digits eclipsed		Aft. Chr.		M. & D.		Middle H.	M.	Digits eclipsed	
1661	☉	Sept.	23	1	36	11	19	1676	☽	June	25	6	26	——	
1661	☽	Oct.	7	14	51	7	4	1676	☉	Dec.	4	20	52	——	
1662	☉	March	19	15	8	——		1677	☉	Nov.	24	12	5	——	
1662	☉	April	12	1	8	——		1677	☽	May	16	16	25	8	15
1663	☽	Feb.	21	16	11	3	14	1678	☽	May	6	5	30	——	
1663	☉	March	9	5	47	——		1678	☽	Oct.	29	9	17	Total	
1663	☽	Aug.	18	8	45	Total		1679	☉	April	10	21	0	——	
1663	☉	Sept.	1	8	8	——		1679	☽	May	25	11	53	5	47
1664	☉	Jan.	27	20	40	——		1680	☉	March	29	23	22	——	
1664	☽	Feb.	11	3	16	——		1680	☉	Sept.	22	7	57	——	
1664	☉	July	22	14	48	——		1680	☽	March	4	Noon		——	
1664	☉	Aug.	20	22	10	——		1681	☉	March	19	13	43	——	
1665	☽	Jan.	30	18	47	4	34	1681	☽	Aug.	28	15	22	10	35
1665	☉	July	12	7	48	——		1681	☉	Sept.	11	15	43	——	
1665	☽	July	26	13	31	0	10	1682	☽	Feb.	21	12	28	Total	
1666	☉	Jan.	4	21	33	——		1682	☽	Aug.	17	18	56	Total	
1666	☉	July	1	19	0	11	10	1683	☉	Jan.	27	1	35	10	30
1667	☽	June	5	Noon		——		1683	☽	Feb.	9	3	39	——	
1667	☉	July	21	2	32	——		1683	☽	Aug.	6	20	36	——	
1667	☉	Nov.	15	11	30	——		1684	☉	Jan.	16	6	34	——	
1668	☉	May	10	Setting		——		1684	☽	June	26	15	18	1	35
1668	☽	May	25	16	26	9	32	1684	☉	July	12	4	26	Total	
1668	☉	Nov.	4	2	53	9	50	1684	☽	Dec.	21	11	18	9	45
1668	☽	Nov.	18	3	54	6	45	1685	☉	Jan.	4	16	0	——	
1669	☉	April	29	18	18	——		1685	☽	June	16	6	0	——	
1669	☉	Oct.	24	10	13	——		1685	☽	Dec.	10	11	26	Total	
1670	☉	April	19	7	0	——		1686	☉	May	21	17	9	——	
1670	☉	Sept.	10	19	0	——		1686	☽	June	6	Noon		——	
1670	☽	Sept.	28	15	43	9	7	1686	☽	Nov.	29	12	22	Total	
1670	☉	Oct.	13	12	5	——		1687	☉	May	11	1	—	*	
1671	☉	April	8	23	29	——		1687	☽	May	26	14	—	*	
1671	☉	Sept.	2	21	25	——		1687	☽	April	15	7	4	6	49
1671	☽	Sept.	18	7	44	Total		1688	☉	April	29	16	27	——	
1672	☉	Feb.	28	3	38	——		1688	☽	Oct.	9	Noon		——	
1672	☽	March	13	3	17	——		1688	☉	Oct.	25	19	40	——	
1672	☉	Aug.	22	6	43	——		1689	☽	April	4	7	42	Total	
1672	☽	Sept.	6	18	54	——		1689	☽	Sept.	28	15	46	Total	
1673	☉	Feb.	16	7	29	——		1690	☉	March	10	——		——	
1673	☉	Aug.	11	21	44	——		1690	☽	March	24	11	14	5	43
1674	☽	Jan.	21	18	22	11	21	1690	☉	Sept.	3	——		——	
1674	☉	Feb.	5	9	4	——		1690	☽	Sept.	18	2	42	——	
1674	☽	July	17	9	40	Total		1691	☉	Feb.	27	17	30	——	
1675	☽	Jan.	11	8	29	Total		1691	☉	Aug.	23	5	51	——	
1675	☉	Jan.	25	10	36	——		1692	☽	Feb.	2	3	20	——	
1675	☽	July	6	16	31	Total		1692	☉	Feb.	16	17	31	——	
1676	☉	June	10	21	26	4	34	1692	☽	July	27	16	9	Total	

Ricciolus's Catalogue of ECLIPSES.

Aft. Chr.		M. & D.	Middle H. M.	Digits eclipsed	Aft. Chr.		M. & D.	Middle H. M.	Digits eclipsed
1693	☽	Jan. 21	17 25	Total	1696	☉	Nov. 23	17 32	——
1693	☽	June 17	Noon	——	1697	☉	April 20	14 32	——
1694	☽	Jan. 11	Noon	——	1697	☽	May 5	18 27	——
1694	☉	June 22	4 22	6 22	1697	☽	Oct. 29	8 44	84 5
1694	☽	July 6	13 51	0 47	1698	☉	April 10	9 13	——
1695	☉	May 11	6 3	——	1698	☉	Oct. 3	15 29	——
1695	☽	May 28	Noon	——	1699	☽	March 15	8 14	9 7
1695	☽	Nov. 20	8 0	6 55	1699	☉	March 30	22 0	——
1695	☉	Dec. 5	17 7		1699	☽	Sept. 8	23 22	——
1696	☽	May 16	12 45	Total	1699	☉	Sept. 23	22 38	9 58
1696	☉	May 30	12 56	——	1700	☽	March 4	20 11	——
1696	☽	Nov. 8	17 30	Total	1700	☽	Aug. 29	1 42	——

The Eclipses from Struyk were observed; those from Ricciolus calculated: the following from *L'Art de verifier les Dates* are only those which are visible in *Europe* for the present century: those which are total are marked with a *T*; and *M* signifies Morning, *A* Afternoon.

Visible ECLIPSES from 1700 to 1800.

Aft. Chr.		Months and Days.	Time of the Day or Night.	Aft. Chr.		Months and Days.	Time of the Day or Night.
1701	☽	Feb. 22	11 A.	1715	☉	May 3	9 M. *T*.
1703	☽	Jan. 3	7 M.	1715	☽	Nov. 11	5 M.
1703	☽	June 29	1 M. *T*.	1717	☽	March 27	3 M.
1703	☽	Dec. 23	7 M. *T*.	1717	☽	May 20	6 A.
1704	☽	Dec. 11	7 M.	1718	☽	Sept. 9	8 A. *T*.
1706	☽	April 28	2 M.	1719	☽	Aug. 29	9 A.
1706	☉	May 12	10 M.	1721	☽	Jan. 13	3 A.
1706	☽	Oct. 21	7 A.	1722	☽	June 29	3 M.
1707	☽	April 17	2 M. *T*.	1722	☉	Dec. 8	3 A.
1708	☽	April 5	6 M.	1722	☽	Dec. 22	4 A.
1708	☉	Dec. 14	8 M.	1724	☉	May 22	7 A. *T*.
1708	☽	Sept. 29	9 A.	1724	☽	Nov. 1	4 M.
1709	☉	March 11	2 A.	1725	☽	Oct. 21	7 A.
1710	☽	Feb. 13	11 A.	1726	☉	Sept. 25	6 A.
1710	☉	Feb. 28	1 A.	1726	☽	Oct. 11	5 M.
1711	☉	July 15	8 A.	1727	☉	Sept. 15	7 M.
1711	☽	July 29	6 A. *T*.	1729	☽	Feb. 13	6 A. *T*.
1712	☽	Jan. 23	8 A.	1729	☽	Aug. 9	1 M.
1713	☽	June 8	6 A.	1730	☽	Feb. 4	4 M.
1713	☽	Dec. 2	4 M.	1731	☽	June 20	2 M.

Visible

Viſible ECLIPSES from 1700 to 1800.

Aft. Chr.		Months and Days.	Time of the Day or Night.	Aft. Chr.		Months and Days.	Time of the Day or Night.
1732	☽	Dec. 1	10 A. *T.*	1764	☉	April 1	10 M.
1733	☉	May 13	7 A.	1764	☽	April 16	1 M.
1733	☽	May 28	7 A.	1765	☉	March 21	2 A.
1735	☽	Oct. 2	1 M.	1765	☉	Aug. 16	5 A.
1736	☽	March 26	12 A. *T.*	1766	☽	Feb. 24	7 A.
1736	☽	Sept. 20	3 M. *T.*	1766	☉	Aug. 5	7 A.
1736	☉	Oct. 4	6 A.	1768	☽	Jan. 4	5 M.
1737	☉	March 1	4 A.	1768	☽	June 30	4 M. *T.*
1737	☽	Sept. 9	4 M.	1768	☽	Dec. 23	4 A. *T.*
1738	☉	Aug. 15	11 M.	1769	☉	June 4	8 M.
1739	☽	Jan. 24	11 A.	1769	☽	Dec. 13	7 M.
1739	☉	Aug. 4	5 A.	1770	☉	Nov. 17	10 M.
1739	☉	Dec. 30	9 M.	1771	☽	April 28	2 M.
1740	☽	Jan. 13	11 A. *T.*	1771	☽	Oct. 23	5 A.
1741	☽	Jan. 1	12 A.	1772	☽	Oct. 11	6 A. *T.*
1743	☽	Nov. 2	3 M. *T.*	1772	☉	Oct. 26	10 M.
1744	☽	Aug. 26	9 A.	1773	☉	March 23	5 M.
1746	☽	Aug. 30	12 A.	1773	☽	Sept. 30	7 A.
1747	☽	Feb. 14	5 M. *T.*	1774	☉	March 12	10 M.
1748	☉	July 25	11 M.	1776	☽	July 31	1 M. *T.*
1748	☽	Aug. 8	12 A.	1776	☉	Aug. 14	5 M.
1749	☽	Dec. 23	8 A.	1777	☉	Jan. 9	5 A.
1750	☉	Jan. 8	9 M.	1778	☉	June 24	4 A.
1750	☽	June 19	9 A. *T.*	1778	☽	Dec. 4	6 M.
1750	☽	Dec. 13	7 M.	1779	☽	May 30	5 M. *T.*
1751	☽	June 9	2 M.	1779	☉	June 14	8 M.
1751	☽	Dec. 2	10 A.	1779	☽	Nov. 23	8 A.
1752	☉	May 13	8 A.	1780	☉	Oct. 27	6 A.
1753	☽	April 17	7 A.	1780	☽	Nov. 12	4 M.
1753	☉	Oct. 26	10 M.	1781	☉	April 23	6 A.
1755	☽	March 28	1 M.	1782	☉	Oct. 17	8 M.
1757	☽	Feb. 4	6 M.	1782	☽	April 12	7 A.
1757	☽	July 30	12 A.	1783	☽	March 18	9 A. *T.*
1758	☽	Jan. 24	7 M. *T.*	1783	☽	Sept. 10	11 A. *T.*
1758	☉	Dec. 30	7 M.	1784	☽	March 7	3 M.
1759	☉	June 24	7 A.	1785	☉	Feb. 9	1 A.
1759	☉	Dec. 19	2 A.	1787	☽	Jan. 3	12 A. *T.*
1760	☽	May 29	9 A.	1787	☉	Jan. 19	10 M.
1760	☉	June 13	7 M.	1787	☉	June 15	5 A.
1760	☽	Nov. 22	9 A.	1787	☽	Dec. 24	3 A.
1761	☽	May 18	11 A. *T.*	1788	☉	June 4	9 M.
1762	☽	May 8	4 M.	1789	☽	Nov. 2	12 A.
1762	☉	Oct. 17	8 M.	1790	☽	April 28	12 A. *T.*
1762	☽	Nov. 1	8 A.	1790	☽	Oct. 23	1 M. *T.*
1763	☉	April 13	8 M.	1791	☉	April 3	1 A.

Visible ECLIPSES from 1700 to 1800.

Aft. Chr.		Months and Days.	Time of the Day or Night.	Aft. Chr.		Months and Days.	Time of the Day or Night.
1791	☽	Oct. 12	3 M.	1795	☽	Feb. 4	1 M.
1792	☉	Sept. 16	11 M.	1795	☉	July 16	9 M.
1793	☽	Feb. 25	10 A.	795	☽	July 31	8 A.
1793	☉	Sept. 5	3 A.	1797	☉	June 25	8 A.
1794	☉	Jan. 31	4 A.	1797	☽	Dec. 4	6 M.
1794	☽	Feb. 14	11 A. *T.*	1798	☽	May 27	7 A. *T.*
1794	☉	Aug. 25	5 A.	1800	☽	Oct. 2	11 A.

328. *A List of Eclipses, and historical Events, which happened about the same Times, from* RICCIOLUS.

Before CHRIST.

754	*July* 5	But according to an old Calendar, this Eclipse of the Sun was on the 21st of *April*, on which day the foundations of *Rome* were laid; if we may believe *Taruntius Firmanus*.
721	*March* 19	A total Eclipse of the Moon. The *Assyrian* Empire at an end; the *Babylonian* established.
585	*May* 28	An Eclipse of the Sun foretold by THALES, by which a peace was brought about between the *Medes* and *Lydians*. Historical Eclipse.
523	*July* 6	An Eclipse of the Moon, which was followed by the death of CAMBYSES.
502	*Nov.* 19	An Eclipse of the Moon, which was followed by the slaughter of the *Sabines*, and death of *Valerius Publicola*.
463	*April* 30	An Eclipse of the Sun. The *Persian* war, and the falling-off of the *Persians* from the *Egyptians*.

An

Before CHRIST.			
431	*April*	25	An Eclipſe of the Moon, which was followed by a great famine at *Rome*; and the beginning of the *Peloponneſian* war.
431	*Auguſt*	3	A total Eclipſe of the Sun. A Comet and Plague at *Athens* *.
413	*Auguſt*	27	A total Eclipſe of the Moon. *Nicias* with his ſhip deſtroyed at *Syracuſe*.
394	*Auguſt*	14	An Eclipſe of the Sun. The *Perſians* beat by *Conon* in a ſea-engagement.
168	*June*	21	A total Eclipſe of the Moon. The next day *Perſeus* King of *Macedonia* was conquered by *Paulus Emilius*.
After CHRIST.			
59	*April*	30	An Eclipſe of the Sun. This is reckoned among the prodigies, on account of the murder of *Agrippinus* by *Nero*.
237	*April*	12	A total Eclipſe of the Sun. A ſign that the reign of the *Gordiani* would not continue long. A ſixth perſecution of the Chriſtians.
306	*July*	27	An Eclipſe of the Sun. The Stars were ſeen, and the Emperor *Conſtantius* died.
840	*May*	4	A dreadful Eclipſe of the Sun. And *Lewis* the Pious died within ſix months after it.
1009	——		An Eclipſe of the Sun. And *Jeruſalem* taken by the *Saracens*.
1133	*Auguſt*	2	A terrible Eclipſe of the Sun. The Stars were ſeen. A ſchiſm in the Church, occaſioned by there being three Popes at once.

* This Eclipſe happened in the firſt year of the Peloponneſian war.

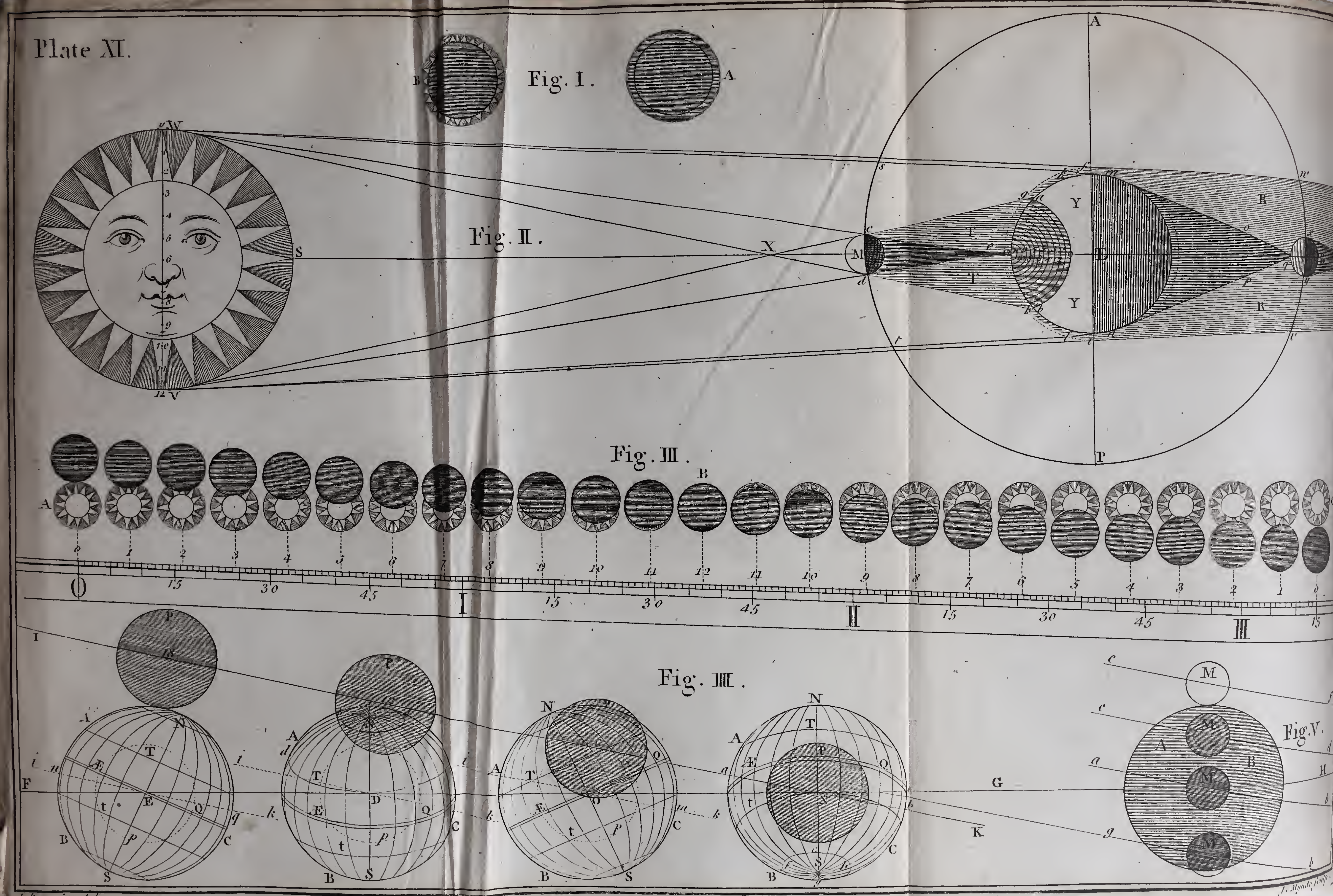


Plate XI.
Fig. I.
Fig. II.
Fig. III.
Fig. IIII.
Fig. V.
J. Ferguson delin.
J. Mynde sculp.

329. I have not cited one half of RICCIOLUS's list of portentous Eclipses; and for the same reason that he declines giving any more of them than what that list contains; namely, that it is most disagreeable to dwell any longer on such nonsense, and as much as possible to avoid tiring the reader: the superstition of the ancients may be seen by the few here copied. My author farther says, that there were treatises written to shew against what regions the malevolent effects of any particular Eclipse was aimed; and the writers affirmed, that the effects of an Eclipse of the Sun continued as many years as the Eclipse lasted hours; and that of the Moon as many months.

The superstitious notions of the ancients with regard to Eclipses,

330. Yet such idle notions were once of no small advantage to CHRISTOPHER COLUMBUS, who, in the year 1493, was driven on the island of *Jamaica*, where he was in the greatest distress for want of provisions, and was moreover refused any assistance from the inhabitants; on which he threatened them with a plague, and told them, that in token of it, there should be an Eclipse: which accordingly fell on the day he had foretold, and so terrified the Barbarians, that they strove who should be first in bringing him all sorts of provisions; throwing them at his feet, and imploring his forgiveness. RICCIOLUS's *Almagest*, Vol. I. l. v. c. ii.

very fortunate once for CHRISTOPHER COLUMBUS.

331. Eclipses of the Sun are more frequent than of the Moon, because the Sun's ecliptic limits are greater than the Moon's, § 317: yet we have more visible Eclipses of the Moon than of the Sun, because Eclipses of the Moon are seen from all parts of that Hemisphere of the Earth which is next her, and are equally great to each of those parts; but the Sun's Eclipses are visible only to that small portion of the Hemisphere next him whereon the Moon's shadow falls, as shall be explaned by and by at large.

Why there are more visible Eclipses of the Moon than of the Sun.

332. The Moon's Orbit being elliptical, and the Earth in one of its focuses, she is once at her

PLATE XI. Fig. I.

least distance from the Earth, and once at her greatest in every Lunation. When the Moon changes at her least distance from the Earth, and so near the Node that her dark shadow falls upon the Earth, she appears big enough to cover the whole * Disc of the Sun from that part on which her shadow falls; and the Sun appears totally eclipsed there, as at *A*, for some minutes: but when the Moon changes at her greatest distance from the Earth, and so near the Node that her dark shadow is directed toward the Earth, her diameter subtends a less angle than the Sun's; and therefore she cannot hide his whole Disc from any part of the Earth, nor does her shadow reach it at that time; and to the place over which the point of her shadow hangs, the Eclipse is annular, as at *B*; the Sun's edge appearing like a luminous ring all around the body of the Moon. When the Change happens within 17 degrees of the Node, and the Moon at her mean distance from the Earth, the point of her shadow just touches the Earth, and she eclipses the Sun totally to that small spot whereon her shadow falls; but the darkness is not of a moment's continuance.

Total and annular Eclipses of the Sun.

The longest duration of total Eclipses of the Sun.

333. The Moon's apparent diameter, when largest, exceeds the Sun's, when least, only 1 minute 38 seconds of a degree: and in the greatest Eclipse of the Sun that can happen at any time and place, the total darkness continues no longer than while the Moon is going 1 minute 38 seconds from the Sun in her Orbit; which is about 3 minutes and 13 seconds of an hour.

To how much of the Earth the Sun may be totally or partially eclipsed at once.

334. The Moon's dark shadow covers only a spot on the Earth's surface, about 180 *English* miles broad, when the Moon's diameter appears largest

* Although the Sun and Moon are spherical bodies, as seen from the Earth they appear to be circular planes; and so would the Earth do, if it were seen from the Moon. The apparently flat surfaces of the Sun and Moon are called their *Discs* by Astronomers.

and

and the Sun's leaft; and the total darknefs can extend no farther than the dark fhadow covers. Yet the Moon's partial fhadow or Penumbra may then cover a circular fpace 4900 miles diameter, within all which the Sun is more or lefs eclipfed, as the places are lefs or more diftant from the center of the Penumbra. When the Moon changes exactly in the Node, the Penumbra is circular on the Earth at the middle of the general Eclipfe; becaufe at that time it falls perpendicularly on the Earth's furface: but at every other moment it falls obliquely, and will therefore be elliptical, and the more fo, as the time is longer before or after the middle of the general Eclipfe; and then, much greater portions of the Earth's furface are involved in the Penumbra.

PLATE XI.

Duration of general and particular Eclipfes.

335. When the Penumbra firft touches the Earth, the general Eclipfe begins: when it leaves the Earth, the general Eclipfe ends: from the beginning to the end the Sun appears eclipfed in fome part of the Earth or other. When the Penumbra touches any place, the Eclipfe begins at that place, and ends when the Penumbra leaves it. When the Moon changes in the Node, the Penumbra goes over the center of the Earth's Difc as feen from the Moon; and confequently, by defcribing the longeft line poffible on the Earth, continues the longeft upon it; namely, at a mean rate, 5 hours 50 minutes: more, if the Moon be at her greateft diftance from the Earth, becaufe fhe then moves floweft; lefs, if fhe be at her leaft diftance, becaufe of her quicker motion.

Fig. II.

336. To make the laft five articles and feveral other phenomena plainer, let *S* be the Sun, *E* the Earth, *M* the Moon, and *AMP* the Moon's Orbit. Draw the right line *Wc* 12 from the weftern fide of the Sun at *W*, touching the weftern fide of the Moon at *c*, and the Earth at 12: draw alfo the right line *Vd* 12 from the eaftern fide of the Sun at *V*, touching the eaftern fide of the Moon at *d*,

 and

and the Earth at 12: the dark ſpace *cc* 12 *d* included between thoſe lines in the Moon's ſhadow, ending in a point at 12, where it touches the Earth; becauſe in this caſe the Moon is ſuppoſed to change at *M* in the middle between *A* the Apogee, or fartheſt point of her Orbit from the Earth, and *P* the Perigee, or neareſt point to it. For, had the point *P* been at *M*, the Moon had been nearer the Earth; and her dark ſhadow at *e* would have covered a ſpace upon it about 180 miles broad, and the Sun would have been totally darkened, as at *A* (Fig. I.) with ſome continuance: but had the point *A* (Fig. II.) been at *M*, the Moon would have been farther from the Earth, and her ſhadow would have ended in a point about *e*, and therefore the Sun would have appeared, as at *B* (Fig. I.) like a luminous ring all around the Moon. Draw the right lines *WXdb* and *Vxcg*, touching the contrary ſides of the Sun and Moon, and ending on the Earth at *a* and *b*: draw alſo the right line *SXM* 12, from the center of the Sun's Diſc, through the Moon's center to the Earth at 12; and ſuppoſe the two former lines *WXdb* and *VXcg* to revolve on the line *SXM* 12 as an Axis, and their points *a* and *b* will deſcribe the limits of the Penumbra *TT* on the Earth's ſurface, including the large ſpace *a* o *b* 12 *a*; within which the Sun appears more or leſs eclipſed, as the places are more or leſs diſtant from the verge of the Penumbra *a* o *b*.

The Moon's dark ſhadow,

and Penumbra,

Digits, what.

Draw the right line *y* 12 acroſs the Sun's Diſc, perpendicular to *SXM*, the Axis of the Penumbra: then, divide the line *y* 12 into twelve equal parts, as in the Figure, for the twelve * Digits of the Sun's diameter: and at equal diſtances from the center of the Penumbra at 12 (on the Earth's ſurface *YY*) to its edge *a*o*b*, draw twelve concentric Circles, as marked with the numeral Figures 1 2 3 4, &c. and remember that the Moon's mo-

* A Digit is a twelfth part of the diameter of the Sun and Moon.

tion in her Orbit *AMP* is from Weſt to Eaſt, as from *s* to *t*. Then, PLATE XI.

The different Phaſes of a ſolar Eclipſe.

To an obſerver on the Earth at *b*, the eaſtern limb of the Moon at *d* ſeems to touch the weſtern limb of the Sun at *W*, when the Moon is at *M*; and the Sun's Eclipſe begins at *b*, appearing as at *A* in Fig. III. at the left hand; but at the ſame moment of abſolute time to an obſerver at *a* in Fig. II. the weſtern edge of the Moon at *c* leaves the eaſtern edge of the Sun at *V*, and the Eclipſe ends, as at the right hand *C* of Fig. III. At the very ſame inſtant, to all thoſe who live on the Circle marked 1 on the Earth *E* in Fig. II. the Moon *M* cuts off or darkens a twelfth part of the Sun *S*, and eclipſes him one Digit, as at 1 in Fig. III: to thoſe who live on the Circle marked 2 in Fig. II. the Moon cuts off two twelfth parts of the Sun, as at 2 in Fig. III: to thoſe on the Circle 3, three parts; and ſo on to the center at 12 in Fig. II. where the Sun is centrally eclipſed, as at *B* in the middle of Fig. III; under which Figure there is a ſcale of hours and minutes, to ſhew at a mean rate how long it is from the beginning to the end of a central Eclipſe of the Sun on the parallel of *London*; and how many Digits are eclipſed at any particular time, from the beginning at *A* to the middle at *B*, or the end at *C*. Thus, in 16 minutes from the beginning, the Sun is two Digits eclipſed; in an hour and five minutes, eight Digits; and in an hour and thirty-ſeven minutes, twelve Digits. Fig. III.

337. By Fig. II. it is plain, that the Sun is totally or centrally eclipſed but to a ſmall part of the Earth at any time; becauſe the dark conical ſhadow *e* of the Moon *M* falls but on a ſmall part of the Earth: and that a partial Eclipſe is confined at that time to the ſpace included by the Circle *a* o *b*, of which only one half can be projected in the Figure, the other half being ſuppoſed to be hid by the convexity of the Earth *E*: and likewiſe, that no part of the Sun is eclipſed to the large ſpace *YY* Fig. II.

 of

PLATE XI. The Velocity of the Moon's ſhadow on the Earth.

of the Earth, becauſe the Moon is not between the Sun and any of that part of the Earth: and therefore to all that part the Eclipſe is inviſible. The Earth turns eaſtward on its Axis, as from *g* to *h*, which is the ſame way that the Moon's ſhadow moves; but the Moon's motion is much ſwifter in her Orbit from *s* to *t*: and therefore, although Eclipſes of the Sun are of longer duration on account of the Earth's motion on its Axis than they would be if that motion was ſtopt, yet in four minutes of time at moſt the Moon's ſwifter motion carries her dark ſhadow quite over any place that its center touches at the time of greateſt obſcuration. The motion of the ſhadow on the Earth's Diſc is equal to the Moon's motion from the Sun, which is about $30\frac{1}{2}$ minutes of a degree every hour at a mean rate; but ſo much of the Moon's Orbit is equal to $30\frac{1}{2}$ degrees of a great Circle on the Earth, § 320; and therefore the Moon's ſhadow goes $30\frac{1}{2}$ degrees or 1830 geographical miles on the Earth in an hour, or $30\frac{1}{2}$ miles in a minute, which is almoſt four times as ſwift as the motion of a cannon-ball.

Fig. IV.

Phenomena of the Earth as ſeen from the Sun or New Moon at different times of the year.

338. As ſeen from the Sun or Moon, the Earth's Axis appears differently inclined every day of the year, on account of keeping its paralleliſm throughout its annual courſe. Let *E*, *D*, *O*, *N* be the Earth at the two Equinoxes and the two Solſtices, *NS* its Axis, *N* the North Pole, *S* the South Pole, *Æ Q* the Equator, *T* the Tropic of Cancer, *t* the Tropic of Capricorn, and *ABC* the Circumference of the Earth's enlightened Diſc as ſeen from the Sun or New Moon at theſe times. The Earth's Axis has the poſition *NES* at the vernal Equinox, lying toward the right hand, as ſeen from the Sun or New Moon; its Poles *N* and *S* being then in the Circumference of the Diſc; and the Equator and all its parallels ſeem to be ſtraight lines, becauſe their planes paſs through the obſerver's eye looking down upon the Earth from the Sun or

Moon directly over *E*, where the Ecliptic *FG* interſects the Equator *Æ*. At the Summer Solſtice, the Earth's Axis has the poſition *NDS*; and that part of the Ecliptic *FG*, in which the Moon is then New, touches the Tropic of Cancer *T* at *D*. The North Pole *N* at that time inclining 23½ degrees toward the Sun, falls ſo many degrees within the Earth's enlightened Diſc, becauſe the Sun is then vertical to *D*, 23½ degrees north of the Equator *ÆQ*; and the Equator with all its parallels ſeem elliptic curves bending downward, or toward the South Pole, as ſeen from the Sun: which Pole, together with 23½ degrees all round it, is hid behind the Diſc in the dark Hemiſphere of the Earth. At the Autumnal Equinox, the Earth's Axis has the poſition *NOS*, lying to the left hand as ſeen from the Sun or New Moon, which are then vertical to *O*, where the Ecliptic cuts the Equator *ÆQ*. Both Poles now lie in the circumference of the Diſc, the North Pole juſt going to diſappear behind it, and the South Pole juſt entering into it; and the Equator with all its parallels ſeem to be ſtraight lines, becauſe their planes paſs through the obſerver's eye, as ſeen from the Sun, and very nearly ſo as ſeen from the Moon. At the Winter Solſtice, the Earth's Axis has the poſition *NNS*; when its South Pole *S*, inclining 23½ degrees toward the Sun, falls 23½ degrees within the enlightened Diſc, as ſeen from the Sun or New Moon, which are then vertical to the Tropic of Capricorn *t*, 23½ degrees ſouth of the Equator *ÆQ*; and the Equator with all its parallels ſeem elliptic curves bending upward; the North Pole being as far behind the Diſc in the dark Hemiſphere, as the South Pole is come into the light. The nearer that any time of the year is to the Equinoxes or Solſtices, the more it partakes of the Phenomena relating to them.

339. Thus it appears, that from the Vernal Equinox to the Autumnal, the North Pole is enlightened;

PLATE XI. Various positions of the Earth's Axis are seen from the Sun at different times of the year.

ed; and the Equator and all its parallels appear elliptical as seen from the Sun, more or less curved as the time is nearer to or farther from the Summer Solstice; and bending downward, or toward the South Pole; the reverse of which happens from the Autumnal Equinox to the Vernal. A little consideration will be sufficient to convince the reader, that the Earth's Axis inclines toward the Sun at the Summer Solstice; from the Sun at the Winter Solstice; and sidewise to the Sun at the Equinoxes; but toward the right hand, as seen from the Sun at the Vernal Equinox; and toward the left hand at the Autumnal. From the Winter to the Summer Solstice, the Earth's Axis, inclines more or less to the right hand, as seen from the Sun; and the contrary from the Summer to the Winter Solstice.

How these positions affect solar Eclipses.

340. The different positions of the Earth's Axis, as seen from the Sun at different times of the year, affect solar Eclipses greatly with regard to particular places; yea so far as would make central Eclipses, which fall at one time of the year, invisible if they had fallen at another, even though the Moon should always change in the Nodes, and at the same hour of the day: of which indefinitely various affections, we shall only give Examples for the times of the Equinoxes and Solstices.

Fig. IV.

In the same Diagram, let *FG* be part of the Ecliptic, and *IK*, *ik*, *ik*, *ik* part of the Moon's Orbit; both seen edgewise, and therefore projected into right lines; and let the intersections *N*, *O*, *D*, *E*, be one and the same Nodes at the above times, when the Earth has the forementioned different positions; and let the space included by the Circles *P*, *p*, *p*, *p*, be the Penumbra at these times, as its center is passing over the center of the Earth's Disc. At the Winter Solstice, when the Earth's Axis has the position *NNS*, the center of the Penumbra *P* touches the Tropic of Capricorn *t* in *N* at the middle of the general Eclipse; but no part

of

of the Penumbra touches the Tropic of Cancer *T*. At the Summer Solstice, when the Earth's Axis has the position *NDS* (*iDk* being then part of the Moon's Orbit, whose Node is at *D*), the Penumbra *p* has its center at *D*, on the Tropic of Cancer *T*, at the middle of the general Eclipse, and then no part of it touches the Tropic of Capricorn *t*. At the Autumnal Equinox, the Earth's Axis has the position *NOS* (*iOk* being then part of the Moon's Orbit), and the Penumbra equally includes part of both Tropics *T* and *t* at the middle of the general Eclipse: at the vernal Equinox it does the same, because the Earth's Axis has the position *NES*: but, in the former of these two last cases, the Penumbra enters the Earth at *A*, north of the Tropic of Cancer *T*, and leaves it at *m*, south of the Tropic of Capricorn *t*; having gone over the Earth obliquely southward, as its center described the line *AOm*: whereas, in the latter case, the Penumbra touches the Earth at *n*, south of the Equator *ÆQ*, and describing the line *nEq* (similar to the former line *AOm* in open space), goes obliquely northward over the Earth, and leaves it at *q*, north of the Equator.

In all these circumstances, the Moon has been supposed to change at noon in her descending Node: had she changed in her ascending Node, the Phenomena would have been as various the contrary way, with respect to the Penumbra's going northward or southward over the Earth. But because the Moon changes at all hours, as often in one Node as in the other, and at all distances from them both at different times as it happens, the variety of the Phases of Eclipses are almost innumerable, even at the same places; considering also how variously the same places are situated on the enlightened Disc of the Earth, with respect to the Penumbra's motion, at the different hours when Eclipses happen.

341. When

How much of the Penumbra falls on the Earth at different diſtances from the Nodes.

341. When the Moon changes 17 degrees ſhort of her deſcending Node, the Penumbra *P* 18 juſt touches the northern part of the Earth's Diſc, near the North Pole *N*; and as ſeen from that place, the Moon appears to touch the Sun, but hides no part of him from ſight. Had the Change been as far ſhort of the aſcending Node, the Penumbra would have touched the ſouthern part of the Diſc near the South Pole *S*. When the Moon changes 12 degrees ſhort of the deſcending Node, more than a third part of the Penumbra *P* 12 falls on the northern parts of the Earth at the middle of the general Eclipſe: had ſhe changed as far paſt the ſame Node, as much of the other ſide of the Penumbra about *P* would have fallen on the ſouthern part of the Earth; all the reſt in the *expanſum*, or open ſpace. When the Moon changes 6 degrees from the Node, almoſt the whole Penumbra *P* 6 falls on the Earth at the middle of the general Eclipſe. And laſtly, when the Moon changes in the Node at *N*, the Penumbra *PN* takes the longeſt courſe poſſible on the Earth's Diſc; its center falling on the middle of it, at the middle of the general Eclipſe. The farther the Moon changes from either Node, within 17 degrees of it, the ſhorter is the Penumbra's continuance on the Earth, becauſe it goes over a leſs proportion of the Diſc, as is evident by the Figure.

The Earth's diurnal motion lengthens the duration of ſolar Eclipſes, which fall without the polar Circles.

342. The nearer that the Penumbra's center is to the Equator at the middle of the general Eclipſe, the longer is the duration of the Eclipſe at all thoſe places where it is central; becauſe, the nearer that any place is to the Equator, the greater is the Circle it deſcribes by the Earth's motion on its Axis; and ſo, the place moving quicker, keeps longer in the Penumbra, whoſe motion is the ſame way with that of the place, though faſter, as has been already mentioned, § 337. Thus (ſee the Earth at *D* and the Penumbra at 12) while the point *b* in the polar Circle *abcd* is carried from *b* to

to *c* by the Earth's diurnal motion, the point *d* on the Tropic of Cancer *T* is carried a much greater length from *d* to *D*: and therefore, if the Penumbra's center goes one time over *c*, and another time over *D*, the Penumbra will be longer in passing over the moving place *d* than it was in passing over the moving place *b*. Consequently, central Eclipses about the Poles are of the shortest duration; and about the Equator, the longest.

343. In the middle of Summer, the whole frigid Zone included by the polar Circle *abcd* is enlightened; and if it then happens that the Penumbra's center goes over the North Pole, the Sun will be eclipsed much the same number of Digits at *a* as at *c*; but while the Penumbra moves eastward over *c*, it moves westward over *a*, because, with respect to the Penumbra, the motions of *a* and *c* are contrary: for *c* moves the same way with the Penumbra toward *d*, but *a* moves the contrary way toward *b*; and therefore the Eclipse will be of longer duration at *c* than at *a*. At *a* the Eclipse, begins on the Sun's eastern limb, but at *c* on his western: at all places lying without the polar Circles, the Sun's Eclipses begin on his western limb, or near it, and end on or near his eastern. At those places where the Penumbra touches the Earth, the Eclipse begins with the rising Sun, on the top of his western or uppermost edge; and at those places where the Penumbra leaves the Earth, the Eclipse ends with the setting Sun, on the top of his eastern edge, which is then the uppermost, just at its disappearing in the Horizon.

And shortens the duration of some which fall within these Circles.

344. If the Moon were surrounded by an Atmosphere of any considerable density, it would seem to touch the Sun a little before the Moon made her appulse to his edge, and we should see a little faintness on that edge before it were eclipsed by the Moon: but as no such faintness has been observed, at least so far as I ever heard, it seems plain, that the Moon has no such Atmosphere as that of

The Moon has no Atmosphere.

PLATE XI. of the Earth. The faint ring of light surrounding the Sun in total Eclipses, called by CASSINI, *la Chevelure du Soleil*, seems to be the Atmosphere of the Sun; because it has been observed to move equally with the Sun, not with the Moon.

345. Having said so much about Eclipses of the Sun, we shall drop that subject at present, and proceed to the doctrine of Lunar Eclipses: which, being more simple, may be explained in less time.

Eclipses of the Moon.

That the Moon can never be eclipsed but at the time of her being Full, and the reason why she is not eclipsed at every Full, has been shewn already, § 316, 317. Let *S* be the Sun, *E* the Earth, *RR* the Earth's shadow, and *B* the Moon in opposition to the Sun: in this situation the Earth intercepts the Sun's light in its way to the Moon; and when the Moon touches the Earth's shadow at *v*, she begins to be eclipsed on her eastern limb *x*, and continues eclipsed until her western limb *y* leaves the shadow at *w*; at *B* she is in the middle of the shadow, and consequently in the middle of the Eclipse.

Fig. II.

346. The Moon when totally eclipsed is not invisible, if she be above the Horizon and the Sky be clear; but appears generally of a dusky colour like tarnished copper, which some have thought to be the Moon's native light. But the true cause of her being visible is the scattered beams of the Sun, bent into the Earth's shadow by going through the Atmosphere; which, being more dense near the Earth than at considerable heights above it, refracts or bends the Sun's rays more inward, § 179; and those which pass nearest the Earth's surface, are bent more than those rays which go through higher parts of the Atmosphere, where it is less dense, until it be so thin or rare as to lose its refractive power. Let the Circle *fghi*, concentric to the Earth, include the Atmosphere, whose refractive power vanishes at the heights *f* and

Why the Moon is visible in a total Eclipse.

and *i*; so that the rays *W f w* and *V i v* go on straight without suffering the least refraction: But all those rays which enter the Atmosphere between *f* and *k*, and between *i* and *l*, on opposite sides of the Earth, are gradually more bent inward as they go through a greater portion of the Atmosphere, until the rays *W k* and *V l* touching the Earth at *m* and *n*, are bent so much as to meet at *q*, a little short of the Moon; and therefore the dark shadow of the Earth is contained in the space *m o q p n*, where none of the Sun's rays can enter: all the rest *RR*, being mixed by the scattered rays which are refracted as above, is in some measure enlightened by them; and some of those rays falling on the Moon, give her the colour of tarnished copper, or of iron almost red-hot. So that if the Earth had no Atmosphere, the Moon would be as invisible in total Eclipses as she is when New. If the Moon were so near the Earth as to go into its dark shadow, suppose about *p o*, she would be invisible during her stay in it; but visible before and after in the fainter shadow *RR*.

PLATE XI.

Why the Sun and Moon are sometimes visible when the Moon is totally eclipsed.

347. When the Moon goes through the center of the Earth's shadow, she is directly opposite to the Sun: yet the Moon has been often seen totally eclipsed in the Horizon when the Sun was also visible in the opposite part of it: for, the horizontal refraction being almost 34 minutes of a degree, § 181, and the diameter of the Sun and Moon being each at a mean state but 32 minutes, the refraction causes both Luminaries to appear above the Horizon when they are really below it, § 179.

Fig. V.

348. When the Moon is Full at 12 degrees from either of her Nodes, she just touches the Earth's shadow, but enters not into it. Let *GH* be the Ecliptic, *e f* the Moon's Orbit where she is 12 degrees from the Node at her Full; *c d* her Orbit where she is 6 degrees from the Node, *a b* her Orbit where she is Full in the Node, *AB* the Earth's

Duration of central Eclipſes of the Moon.

Earth's ſhadow, and *M* the Moon. When the Moon deſcribes the line *e f*, ſhe juſt touches the ſhadow, but does not enter into it; when ſhe deſcribes the line *c d*, ſhe is totally, though not centrally, immerſed in the ſhadow; and when ſhe deſcribes the line *ab*, ſhe paſſes by the Node at *M* in the center of the ſhadow, and takes the longeſt line poſſible, which is a diameter, through it: and ſuch an Eclipſe being both total and central, is of the longeſt duration, namely, 3 hours 57 minutes 6 ſeconds from the beginning to the end, if the Moon be at her greateſt diſtance from the Earth: and 3 hours 37 minutes 26 ſeconds, if ſhe be at her leaſt diſtance. The reaſon of this difference is, that when the Moon is fartheſt from the Earth, ſhe moves the ſloweſt; and when neareſt to it, quickeſt.

Digits.

349. The Moon's diameter, as well as the Sun's, is ſuppoſed to be divided into twelve equal parts called *Digits*; and ſo many of theſe parts as are darkened by the Earth's ſhadow, ſo many Digits is the Moon eclipſed. All that the Moon is eclipſed above 12 Digits, ſhew how far the ſhadow of the Earth is over the body of the Moon, on that edge to which ſhe is neareſt at the middle of the Eclipſe.

Why the beginning and end of a lunar Eclipſe is ſo difficult to be determined by obſervation.

350. It is difficult to obſerve exactly either the beginning or ending of a lunar Eclipſe, even with a good Teleſcope; becauſe the Earth's ſhadow is ſo faint and ill-defined about the edges, that when the Moon is either juſt touching or leaving it, the obſcuration of her limb is ſcarce ſenſible; and therefore the niceſt obſervers can hardly be certain to ſeveral ſeconds of time. But both the beginning and ending of ſolar Eclipſes are viſibly inſtantaneous; for the moment that the edge of the Moon's Diſc touches the Sun's, his roundneſs ſeems a little broken on that part; and the moment ſhe leaves it, he appears perfectly round again.

351. In

351. In Aſtronomy, Eclipſes of the Moon are of great uſe for aſcertaining the periods of her motions; eſpecially ſuch Eclipſes as are obſerved to be alike in all circumſtances, and have long intervals of time between them. In Geography, the Longitudes of places are found by Eclipſes, as already ſhewn in the Eleventh Chapter. In Chronology, both ſolar and lunar Eclipſes ſerve to determine exactly the time of any paſt event: for there are ſo many particulars obſervable in every Eclipſe, with reſpect to its quantity, the places where it is viſible (if of the Sun), and the time of the day or night; that it is impoſſible there can be two ſolar Eclipſes in the courſe of many ages which are alike in all circumſtances.

The uſe of Eclipſes in Aſtronomy, Geography, and Chronology.

352. From the above explanation of the doctrine of Eclipſes, it is evident that the darkneſs at our SAVIOUR's Crucifixion was ſupernatural. For he ſuffered on the day on which the Paſſover was eaten by the *Jews*, on which day it was impoſſible that the Moon's ſhadow could fall on the Earth; for the *Jews* kept the Paſſover at the time of Full Moon: nor does the darkneſs in total Eclipſes of the Sun laſt above four minutes in any place, § 333; whereas the darkneſs at the Crucifixion laſted three hours, *Matt.* xxviii. 15. and overſpread at leaſt all the land of *Judea*.

The darkneſs at our SAVIOUR's Crucifixion, ſupernatural.

CHAP.

CHAP. XIX.

Shewing the Principles on which the following Astronomical Tables are constructed, and the Method of calculating the Times of New and Full Moons and Eclipses by them.

353. THE nearer that any object is to the eye of an observer, the greater is the angle under which it appears: the farther from the eye, the less.

The diameters of the Sun and Moon subtend different angles at different times. And, at equal intervals of time, these angles are once at the greatest, and once at the least; in somewhat more than a complete revolution of the Luminary through the Ecliptic, from any given fixed Star to the same Star again. — This proves that the Sun and Moon are constantly changing their distances from the Earth; and that they are once at their greatest distance, and once at their least, in little more than a complete revolution.

The gradual differences of these angles are not what they would be, if the Luminaries moved in circular Orbits, the Earth being supposed to be placed at some distance from the center: but they agree perfectly with elliptic orbits, supposing the lower focus of each orbit to be at the center of the Earth.

The farthest point of each Orbit from the Earth's center is called the *Apogee*, and the nearest point is called the *Perigee*.— These points are directly opposite to each other.

Astronomers divide each Orbit into 12 equal parts, called *Signs*; each sign into 30 equal parts, called *Degrees*; each degree into 60 equal parts, called *Minutes*; and every minute into 60 equal parts, called *Seconds*. The distance of the Sun or Moon from any given point of its orbit, is reckoned

koned in ſigns, degrees, minutes, and ſeconds. Here we mean the diſtance that the Luminary has moved through from any given point; not the ſpace it is ſhort of it in coming round again, though ever ſo little.

The diſtance of the Sun or Moon from its Apogee, at any given time, is called its *mean Anomaly:* ſo that, in the Apogee, the Anomaly is nothing; in the Perigee, it is ſix ſigns.

The motions of the Sun and Moon are obſerved to be continually accelerated from the Apogee to the Perigee, and as gradually retarded from the Perigee to the Apogee; being ſloweſt of all when the mean Anomaly is nothing, and ſwifteſt of all when it is ſix ſigns.

When the Luminary is in its Apogee or its Perigee, its place is the ſame as it would be, if its motion were equable in all parts of its Orbit.—The ſuppoſed equable motions are called *mean;* the unequable are juſtly called the *true.*

The mean place of the Sun or Moon is always forwarder than the true place*, while the Luminary is moving from its Apogee to its Perigee; and the true place is always forwarder than the mean, while the Luminary is moving from its Perigee to its Apogee.—In the former caſe, the Anomaly is always leſs than ſix ſigns; and in the latter caſe, more.

It has been found, by a long ſeries of obſervations, that the Sun goes through the Ecliptic, from the *Vernal Equinox* to the ſame Equinox again, in 365 days 5 hours 48 minutes 55 ſeconds: from the *firſt Star of Aries* to the ſame Star again, in 365 days 6 hours 9 minutes 24 ſeconds: and from his *Apogee* to the ſame again, in 365 days 6 hours 14 minutes 0 ſeconds.—The firſt of theſe is called the *Solar Year*, the ſecond the *Sydereal Year*, and the third

* The point of the Ecliptic in which the Sun or Moon is at any given moment of time, is called the *place* of the Sun or Moon at that time.

the *Anomalistic Year.* So that the Solar Year is 20 minutes 29 seconds shorter than the Sydereal; and the Sydereal Year is 4 minutes 36 seconds shorter than the Anomalistic.—Hence it appears, that the *Equinoctial Point*, or intersection of the Ecliptic and Equator at the beginning of Aries, goes backward with respect to the fixed Stars, and that the Sun's Apogee goes forward.

It is also observed, that the Moon goes through her Orbit, from any given fixed Star to the same Star again, in 27 days 7 hours 43 minutes 4 seconds, at a mean rate: from her Apogee to her Apogee again, in 27 days 13 hours 18 minutes 43 seconds: and from the Sun to the Sun again, in 29 days 12 hours 44 minutes $3\frac{1}{10}$ seconds.—This shews, that the Moon's Apogee moves forward in the Ecliptic, and *that* at a much quicker rate than the Sun's Apogee does; since the Moon is five hours 55 minutes 39 seconds longer in revolving from her Apogee to her Apogee again, than from any Star to the same Star again.

The Moon's Orbit crosses the Ecliptic in two opposite points, which are called her *Nodes:* and it is observed that she revolves sooner from any Node to the same Node again, than from any Star to the same Star again, by 2 hours 38 minutes 27 seconds, which shews that her nodes move backward, or contrary to the order of signs, in the Ecliptic.

The time in which the Moon revolves from the Sun to the Sun again (or from change to change) is called a *Lunation*; which, according to Dr. Pound's mean measures, would always consist of 29 days 12 hours 44 minutes 3 seconds 2 thirds 58 fourths, if the motions of the Sun and Moon were always equable *.—Hence, 12 mean Luna-

* We have thought proper to keep by Dr. *Pound*'s length of a mean Lunation, because his numbers come nearer to the times of the ancient Eclipses, than *Mayer*'s do, without allowing for the Moon's acceleration.

tions contain 354 days 8 hours 48 minutes 36 seconds 35 thirds 40 fourths, which is 10 days 21 hours 11 minutes 23 seconds 24 thirds 20 fourths less than the length of a common *Julian year*, consisting of 365 days 6 hours; and 13 mean Lunations contain 383 days 21 hours 32 minutes 39 seconds 38 thirds 38 fourths, which exceeds the length of a common *Julian year* by 18 days 15 hours 32 minutes 39 seconds 38 thirds 38 fourths.

The mean time of New Moon being found for any given year and month, as suppose for *March* 1700, Old Stile, if this mean New Moon falls later than the 11th day of *March*, then, 12 mean Lunations added to the time of this mean New Moon, will give the time of the mean New Moon in *March* 1701, after having thrown off 365 days.— But, when the mean New Moon happens to be before the 11th of *March*, we must add 13 mean Lunations, in order to have the time of mean New Moon in *March* the year following: always taking care to subtract 365 days in common years, and 366 days in leap-years, from the sum of this addition.

Thus, *A. D.* 1700, Old Stile, the time of mean New Moon in *March* was the 8th day, at 16 hours 11 minutes 25 seconds after the noon of that day (*viz.* at 11 minutes 25 seconds past IV. in the morning of the 9th day according to common reckoning). To this we must add 13 mean Lunations, or 383 days 21 hours 32 minutes 39 seconds 38 thirds 38 fourths, and the sum will be 392 days 13 hours 44 minutes 4 seconds 38 thirds 38 fourths; from which subtract 365 days, because the year 1701 is a common year, and there will remain 27 days 13 hours 44 minutes 4 seconds 38 thirds 38 fourths for the time of mean New Moon in *March*, *A. D.* 1701.

Carrying on this addition and subtraction till *A. D.* 1703, we find the time of mean New Moon in *March* that year, to be on the 6th day, at 7 hours 21 minutes 17 seconds 49 thirds 46 fourths past noon; to which add 13 mean Lunations, and the sum will be 390 days 4 hours 53 minutes 57 seconds 28 thirds 20 fourths; from which subtract 366 days, because the year 1704 is a leap-year, and there will remain 24 days 4 hours 53 minutes 57 seconds 28 thirds 20 fourths, for the time of mean New Moon in *March*, *A. D.* 1704.

In this manner was the first of the following Tables constructed to seconds, thirds, and fourths; and then wrote out to the nearest seconds.—The reason why we chose to begin the year with *March*, was to avoid the inconvenience of adding a day to the tabular time in leap-years after *February*, or subtracting a day therefrom in *January* and *February* in those years; to which all tables of this kind are subject, which begin the year with *January*, in calculating the times of New or Full Moons.

The mean Anomalies of the Sun and Moon, and the Sun's mean motion from the Ascending Node of the Moon's Orbit, are set down in Table III. from one to 13 mean Lunations.—These Numbers, for 13 Lunations, being added to the radical Anomalies of the Sun and Moon, and to the Sun's mean distance from the ascending Node, at the time of mean New Moon in *March* 1700, (Table I.) will give their mean Anomalies, and the Sun's mean distance from the Node, at the time of mean New Moon in *March* 1701; and being added for 12 Lunations to those for 1701, give them for the time of mean New Noon in *March* 1702. And so on, as far as you please to continue the Table (which is here carried on to the year 1800) always throwing off 12 signs when their sum exceeds 12, and setting down the remainder as the proper quantity.

If the Numbers belonging to *A. D.* 1700 (in Table I.) be subtracted from those belonging to 1800, we shall have their whole differences in 100 complete Julian years; which accordingly we find to

4

to be 4 days 8 hours 10 minutes 52 seconds 15 thirds 40 fourths, with respect to the time of mean New Moon.—These being added together 60 times (always taking care to throw off a whole Lunation when the days exceed 29½) making up 60 centuries, or 6000 years, as in Table VI. which was carried on to seconds, thirds, and fourths; and then wrote out to the nearest seconds. In the same manner were the respective Anomalies and the Sun's distance from the Node found, for these centurial years; and then (for want of room) wrote out only to the nearest minutes, which is sufficient in whole centuries.—By means of these two Tables, we may find the time of any mean New Moon in *March*, together with the Anomalies of the Sun and Moon, and the Sun's distance from the Node, at these times, within the limits of 6000 years, either before or after any given year in the 18th century; and the mean time of any New or Full Moon in any given month after *March*, by means of the third and fourth Tables, within the same limits, as shewn in the precepts for calculation.

Thus it would be a very easy matter to calculate the time of any New or Full Moon, if the Sun and Moon moved equably in all parts of their Orbits.—But we have already shewn that their places are never the same as they would be by equable motions, except when they are in Apogee or Perigee; which is, when their mean Anomalies are either nothing, or six signs: and that their mean places are always forwarder than their true places, while the Anomaly is less than six signs; and their true places are forwarder than the mean, while the Anomaly is more.

Hence it is evident, that while the Sun's Anomaly is less than six signs, the Moon will overtake him, or be opposite to him, sooner than she could if his motion were equable; and later while his Anomaly is more than six signs.—The greatest difference that can possibly happen between the mean and true time of New or Full Moon, on account of the inequality of the Sun's motion, is 3 hours 48 minutes 28 seconds: and that is, when the Sun's Anomaly is either 3 signs 1 degree, or 8 signs 29 degrees sooner in the first case, and later in the last.—In all other signs and degrees of Anomaly, the difference is gradually less, and vanishes when the Anomaly is either nothing or six signs.

The Sun is in his Apogee on the 30th of *June*, and in his Perigee on the 30th of *December*, in the present age: so that he is nearer the Earth in our winter than in our summer. The proportional difference of distance, deduced from the difference of the Sun's apparent diameter at these times, is as 983 to 1017.

The Moon's orbit is dilated in winter, and contracted in summer; therefore, the Lunations are longer in winter than in summer. The greatest difference is found to be 22 minutes 29 seconds: the Lunations increasing gradually in length while the Sun is moving from his Apogee to his Perigee, and decreasing in length while he is moving from his Perigee to his Apogee.—On this account, the Moon will be later every time in coming to her conjunction with the Sun, or being in opposition to him, from *December* till *June*, and sooner from *June* to *December*, than if her orbit had continued of the same size all the year round.

As both these differences depend on the Sun's Anomaly, they may be fitly put together into one Table, and called *The annual, or first equation of the mean to the true * syzygy* (see Table VII.). This equational difference is to be subtracted from the time of the mean syzygy when the Sun's Anomaly is less than six signs, and added when the Anomaly is more.—At the greatest, it is 4 hours 10 minutes 57 seconds, *viz.* 3 hours 48 minutes 28 seconds, on account of the Sun's unequal motion, and 22

* The word *syzygy* signifies both the conjunction and opposition of the Sun and Moon.

minutes

minutes 29 ſeconds, on account of the dilatation of the Moon's orbit.

This compound equation would be ſufficient for reducing the mean time of New or Full Moon to the true time, if the Moon's orbit were of a circular form, and her motion quite equable in it.—But the Moon's Orbit is more elliptical than the Sun's, and her motion in it ſo much the more unequal. The difference is ſo great, that ſhe is ſometimes in conjunction with the Sun, or in oppoſition to him, ſooner by 9 hours 47 minutes 54 ſeconds, than ſhe would be if her motion were equable; and at other times as much later.—The former happens when her mean Anomaly is 9 ſigns 4 degrees, and the latter when it is 2 ſigns 26 degrees. *See* Table IX.

At different diſtances of the Sun from the Moon's Apogee, the Figure of the Moon's Orbit becomes different.—It is longeſt of all, or moſt excentric, when the Sun is in the ſame ſign and degree either with the Moon's Apogee or Perigee; ſhorteſt of all, or leaſt excentric, when the Sun's diſtance from the Moon's Apogee is either three ſigns or nine ſigns; and at a mean ſtate when the diſtance is either 1 ſign 15 degrees, 4 ſigns 15 degrees, 7 ſigns 15 degrees, or 10 ſigns 15 degrees.—When the Moon's Orbit is at its greateſt excentricity, her apogeal diſtance from the Earth's center is to her perigeal diſtance from it, as 1067 is to 933; when leaſt excentric, as 1043 is to 957; and when at the mean ſtate, as 1055 is to 945.

But the Sun's diſtance from the Moon's Apogee is equal to the quantity of the Moon's mean Anomaly at the time of New Moon, and by the addition of ſix ſigns, it becomes equal in quantity to the Moon's mean Anomaly at the time of Full Moon.—Therefore a table may be conſtructed ſo as to anſwer all the various inequalities depending on the different excentricities of the Moon's Orbit, in the ſyzygies; and called *The ſecond equation of* *the mean to the true syzygy* (see Table IX.); and the Moon's Anomaly, when equated by Table VIII. may be made the proper argument for taking out this second equation of time, which must be added to the former equated time, when the Moon's Anomaly is less than six signs, and subtracted when the Anomaly is more.

There are several other inequalities in the Moon's motion, which sometimes bring on the true syzygy a little sooner, and at other times keep it back a little later than it would otherwise be: but they are so small, that they may be all omitted except two; the former of which (*see* Table X.) depends on the difference between the Anomalies of the Sun and Moon in the syzygies, and the latter (*see* Table XI.) depends on the Sun's distance from the Moon's Nodes at these times.—The greatest difference arising from the former, is 4 minutes 58 seconds; and from the latter, 1 minute 34 seconds.

Having described the Phenomena arising from the inequalities of the Solar and Lunar Motions, we shall now shew the reasons of these inequalities.

In all calculations relating to the Sun and Moon, we consider the Sun as a moving body, and the Earth as a body at rest; since all the Appearances are the same, whether it be the Sun or the Earth that moves.—But the truth is, that the Sun is at rest, and the Earth moves round him once a year, in the plane of the Ecliptic. Therefore, whatever sign and degree of the Ecliptic the Earth is in, at any given time, the Sun will then appear to be in the opposite sign and degree.

The nearer that any body is to the Sun, the more it is attracted by him; and this attraction increases as the square of the distance diminishes; and *vice versâ*.

The Earth's annual Orbit is elliptical, and the Sun is placed in one of its focuses. The remotest point

point of the Earth's Orbit from the Sun is called *The Earth's Aphelion*; and the nearest point of the Earth's Orbit to the Sun is called *The Earth's Perihelion.*—When the Earth is in its Aphelion, the Sun appears to be in its Apogee; and when the Earth is in its Perihelion, the Sun appears to be in its Perigee.

As the Earth moves from its Aphelion to its Perihelion, it is constantly more and more attracted by the Sun; and this attraction, by conspiring in some degree with the Earth's motion, must necessarily accelerate it. But as the Earth moves from its Perihelion to its Aphelion, it is continually less and less attracted by the Sun; and as this attraction acts then just as much against the Earth's motion, as it acted for it in the other half of the Orbit, it retards the motion in the like degree.—The faster the Earth moves, the faster will the Sun appear to move; the slower the Earth moves, the slower is the Sun's apparent motion.

The Moon's Orbit is also elliptical, and the Earth keeps constantly in one of its focuses.—The Earth's attraction has the same kind of influence on the Moon's motion, as the Sun's attraction has on the motion of the Earth: and therefore, the Moon's motion must be continually accelerated while she is passing from her Apogee to her Perigee; and as gradually retarded in moving from her Perigee to her Apogee.

At the time of New Moon, the Moon is nearer the Sun than the Earth is at that time, by the whole semidiameter of the Moon's Orbit; which, at a mean state, is 240,000 miles; and at the Full, she is as much farther from the Sun than the Earth then is.—Consequently, the Sun attracts the Moon more than it attracts the Earth in the former case, and less in the latter. The difference is greatest when the Earth is nearest the Sun, and least when it is farthest from him. The obvious result of this is, that as the Earth is nearest

to

to the Sun in winter, and fartheſt from him in ſummer, the Moon's Orbit muſt be dilated in winter, and contracted in ſummer.

Theſe are the principal cauſes of the difference of time, that generally happen between the mean and true times of conjunction or oppoſition of the Sun and Moon. As to the other two differences, *viz.* thoſe which depend on the difference between the Anomalies of the Sun and Moon, and upon the Sun's diſtance from the lunar Nodes, in the ſyzygies, they are owing to the different degrees of attraction of the Sun and Earth upon the Moon, at greater or leſs diſtances, according to their reſpective Anomalies, and to the poſition of the Moon's Nodes with reſpect to the Sun.

If ever it ſhould happen, that the Anomalies of both the Sun and Moon were either nothing or ſix ſigns, at the mean time of New or Full Moon, and the Sun ſhould then be in conjunction with either of the Moon's Nodes, all the above-mentioned equations would vaniſh, and the mean and true time of the ſyzygy would coincide. But if ever this circumſtance did happen, we cannot expect the like again in many ages afterward.

Every 49th Lunation, (or Courſe of the Moon from Change to Change) returns very nearly to the ſame time of the day as before. For, in 49 mean Lunations there are 1446 days 23 hours 58 minutes 29 ſeconds 25 thirds, which wants but 1 minute 30 ſeconds 34 thirds of 1477 days.

In 2953059085108 days, there are 100000000000 mean Lunations exactly: and this is the ſmalleſt number of natural days in which any exact number of mean Lunations are completed.

TABLE I. *The mean Time of New Moon in* March, *Old Stile; with the mean Anomalies of the Sun and Moon, and the Sun's mean Distance from the Moon's Ascending Node, from* A. D. 1700 *to* A. D. 1800 *inclusive.*

Y. of Chr.	Mean New Moon in March.				Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's mean Dist. from the Node.			
	D.	H.	M.	S.	s	°	'	"	s	°	'	"	s	°	'	"
1700	8	16	11	25	8	19	58	48	1	22	30	37	6	14	31	7
1701	27	13	44	5	9	8	20	59	0	28	7	42	7	23	14	8
1702	16	22	32	41	8	27	36	51	11	7	55	47	8	1	16	55
1703	6	7	21	18	8	16	52	43	9	17	43	52	8	9	19	42
1704	24	4	53	57	9	5	14	54	8	23	20	57	9	18	2	43
1705	13	13	42	34	8	24	30	47	7	3	9	2	9	26	5	30
1706	2	22	31	11	8	13	46	39	5	12	57	7	10	4	8	17
1707	31	20	3	50	9	2	8	50	4	18	34	13	11	12	51	18
1708	10	4	52	27	8	21	24	43	2	28	22	18	11	20	54	5
1709	29	2	25	7	9	9	46	54	2	3	59	24	0	29	37	6
1710	18	11	13	43	8	29	2	47	0	13	47	30	1	7	39	54
1711	7	20	2	20	8	18	18	39	10	23	35	36	1	15	42	41
1712	25	17	34	59	9	6	40	51	9	29	12	42	2	14	25	43
1713	15	2	23	36	8	25	56	43	8	9	0	47	3	2	28	30
1714	4	11	12	13	8	15	12	35	6	18	48	52	3	10	31	17
1715	23	8	44	52	9	3	34	47	5	24	25	57	4	19	14	18
1716	11	17	33	29	8	22	50	39	4	4	14	2	4	27	17	5
1717	1	2	22	5	8	12	6	32	2	14	2	8	5	5	19	52
1718	19	23	54	45	9	0	28	44	1	19	39	13	6	14	2	54
1719	9	8	43	22	8	19	44	37	11	29	27	18	6	22	5	41
1720	27	6	16	1	9	8	6	49	11	5	4	24	8	0	48	43
1721	16	15	4	38	8	27	22	41	9	14	52	29	8	8	51	29
1722	5	23	53	14	8	16	38	33	7	24	40	34	8	16	54	16
1723	24	21	25	54	9	5	0	45	7	0	17	40	9	25	37	18
1724	13	6	14	31	8	24	16	37	5	10	5	45	10	3	40	5
1725	2	15	3	7	8	13	32	29	3	19	53	50	10	11	42	52
1726	21	12	35	47	9	1	54	41	2	25	30	56	11	20	25	54
1727	10	21	24	23	8	21	10	34	1	5	19	1	11	28	28	41
1728	28	18	57	3	9	9	52	46	0	10	56	7	1	7	11	42
1729	18	3	45	40	8	28	48	39	10	20	44	12	1	15	14	29
1730	7	12	34	16	8	18	4	31	9	0	32	17	1	23	17	16
1731	26	10	6	56	9	6	26	42	8	6	9	23	3	2	0	17
1732	14	18	55	33	8	25	42	34	6	15	57	28	3	10	3	4

TABLE I. *continued.* *Old Stile.*

Y. of Chr.	Mean New Moon in March.				Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's mean Dist from the Node.			
	D.	H.	M.	S.	s	°	'	"	s	°	'	"	s	°	'	"
1733	4	3	44	9	8	14	58	26	4	25	45	33	3	18	5	51
1734	23	1	16	49	9	3	20	38	4	1	22	39	4	26	48	53
1735	12	10	5	25	8	22	36	30	2	11	10	44	5	4	51	40
1736	0	18	54	2	8	11	52	22	0	20	58	49	5	12	54	27
1737	19	16	26	42	9	0	14	34	11	26	35	55	6	21	37	29
1738	9	1	15	18	8	19	30	26	10	6	24	0	6	29	40	16
1739	27	22	47	58	9	7	52	38	9	12	1	6	8	8	23	18
1740	16	7	36	34	8	27	8	30	7	21	49	11	8	16	26	5
1741	5	16	25	11	8	16	24	22	6	1	37	16	8	24	28	52
1742	24	13	57	52	9	4	46	34	5	7	14	22	10	3	11	54
1743	13	22	46	27	8	24	2	27	3	17	2	27	10	1	14	41
1744	2	7	35	4	8	13	18	20	1	26	50	32	10	19	17	28
1745	21	5	7	44	9	1	40	32	1	2	27	38	11	28	0	30
1746	10	13	56	20	8	20	56	24	11	12	15	43	0	6	3	17
1747	29	11	29	0	9	9	18	36	10	17	52	49	1	14	46	19
1748	17	20	17	36	8	28	34	28	8	27	40	54	1	22	49	5
1749	7	5	6	13	8	17	50	20	7	7	28	59	2	0	51	52
1750	26	2	38	53	9	6	12	32	6	13	6	5	3	9	34	53
1751	15	11	27	29	8	25	28	24	4	22	54	10	3	17	37	40
1752	3	20	16	6	8	14	44	16	3	2	42	15	3	35	40	27
1753	22	17	48	45	9	3	6	28	2	8	19	21	5	4	23	28
1754	12	2	37	22	8	22	22	20	0	18	7	26	5	12	26	15
1755	1	11	25	59	8	11	38	12	10	27	55	31	5	20	29	2
1756	19	8	58	38	9	0	0	24	10	3	32	37	6	29	12	3
1757	8	17	47	15	8	19	16	16	8	13	20	42	7	7	14	50
1758	27	15	19	54	9	7	38	28	7	18	57	48	8	15	57	52
1759	17	0	8	31	8	26	54	20	5	28	45	54	8	24	0	39
1760	5	8	57	8	8	16	10	12	4	8	34	0	9	2	3	26
1761	24	6	29	47	9	4	32	24	3	14	11	6	10	10	46	27
1762	13	15	18	24	8	23	48	16	1	23	59	11	10	18	49	14
1763	3	0	7	1	8	13	4	8	0	3	47	16	10	26	52	1
1764	20	21	39	40	9	1	26	20	11	9	24	21	0	5	35	2
1765	10	6	28	17	8	20	42	13	9	19	12	26	0	13	37	49
1766	29	4	0	56	9	9	4	20	8	24	49	32	1	22	20	51

TABLE I. *concluded.* *Old Stile.*

Y. of Chr.	Mean New Moon in March.				Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's mean Dist. from the Node.			
	D.	H.	M.	S.	s	°	'	"	s	°	'	"	s	°	'	"
1767	18	12	49	33	8	28	20	17	7	4	37	37	2	0	23	38
1768	6	21	38	10	8	17	36	9	5	14	25	42	2	8	26	25
1769	25	19	10	40	9	5	58	21	4	20	2	48	3	17	9	27
1770	15	3	59	26	8	25	14	13	2	29	50	53	3	25	12	14
1771	4	12	48	2	8	14	30	5	1	9	38	58	4	3	15	1
1772	22	10	20	43	9	2	52	17	0	15	16	4	5	11	58	3
1773	11	19	9	19	8	22	8	9	10	25	4	9	5	20	0	50
1774	1	3	57	55	8	11	24	1	9	4	52	14	5	28	3	37
1775	20	1	30	35	8	29	46	13	8	10	29	20	7	6	49	38
1776	8	10	19	12	8	19	2	5	6	20	17	25	7	14	49	25
1777	27	7	51	51	9	7	24	17	5	25	54	31	8	23	32	26
1778	16	16	40	28	8	26	40	9	4	5	42	36	9	1	35	13
1779	6	1	29	4	8	15	56	1	2	15	30	41	9	9	38	0
1780	23	23	1	44	9	4	18	13	1	21	7	47	10	18	21	1
1781	13	7	50	21	8	23	34	5	0	0	55	52	10	26	23	48
1782	2	16	38	57	8	12	49	58	10	10	43	57	11	4	26	35
1783	21	14	11	37	9	1	12	10	9	16	21	3	0	13	9	36
1784	9	23	0	13	8	20	28	3	7	26	9	8	0	21	12	23
1785	28	20	32	53	9	8	50	15	7	1	46	14	1	29	55	25
1786	18	5	21	30	8	28	6	7	5	11	34	19	2	7	58	12
1787	7	14	10	6	8	17	21	59	3	21	22	24	2	16	0	59
1788	25	11	42	46	9	5	44	11	2	26	59	30	3	24	44	1
1789	14	20	31	23	8	25	0	3	1	6	47	35	4	2	46	48
1790	4	5	19	59	8	14	15	55	11	16	35	40	4	10	49	35
1791	23	2	52	39	9	2	38	7	10	22	12	46	5	19	32	37
1792	11	11	41	15	8	21	53	59	9	2	0	52	5	27	35	24
1793	30	9	13	55	9	10	16	11	8	7	37	58	7	6	18	26
1794	19	18	2	32	8	29	32	3	6	17	26	4	7	14	21	13
1795	9	2	51	8	8	18	47	55	4	27	14	9	7	22	24	0
1796	27	0	23	48	9	7	10	7	4	2	51	14	9	1	7	1
1797	16	9	12	24	8	26	25	59	2	12	39	19	9	9	9	48
1798	5	18	1	1	8	15	41	51	0	22	27	25	9	17	12	35
1799	24	15	23	41	9	4	4	3	11	28	4	31	10	25	55	37
1800	13	0	22	17	8	23	19	55	10	7	52	36	11	3	58	24

TABLE

TABLE II. *Mean New Moon, &c. in* March, *New Stile, from* A. D. 1752 *to* A. D. 1800.

Y. of Chr.	Mean New Moon in March.				Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's mean Dist. from the Node.			
	D.	H.	M.	S.	s	°	'	"	s	°	'	"	s	°	'	"
1752	14	20	16	6	8	14	44	16	3	2	42	15	3	25	40	27
1753	4	5	4	42	8	4	0	8	1	12	30	20	4	3	43	14
1754	23	2	37	22	8	22	22	20	0	18	7	26	5	12	26	15
1755	12	11	25	59	8	11	38	12	10	27	55	31	5	20	29	2
1756	30	8	58	38	9	0	0	24	10	3	32	37	6	29	12	3
1757	19	17	47	15	8	19	16	16	8	13	20	42	7	7	14	50
1758	9	2	35	51	8	8	32	8	6	23	8	47	7	15	17	38
1759	28	0	8	31	8	26	54	20	5	28	45	54	8	24	0	39
1760	16	8	57	8	8	16	10	12	4	8	34	0	9	2	3	26
1761	5	17	45	44	8	5	26	4	2	18	22	5	9	10	6	13
1762	24	15	18	24	8	23	48	16	1	23	59	11	10	18	49	14
1763	14	0	7	1	8	13	4	8	0	3	47	16	10	26	52	1
1764	2	8	55	36	8	2	20	0	10	13	35	21	11	4	54	48
1765	21	6	28	17	8	20	42	13	9	19	12	26	0	13	37	49
1766	10	15	16	53	8	9	58	5	7	29	0	31	0	21	40	37
1767	29	12	49	33	8	28	20	17	7	4	37	37	2	0	23	38
1768	17	21	38	9	8	17	36	9	5	14	25	42	2	8	26	25
1769	7	6	26	46	8	6	52	1	3	24	13	47	2	16	29	13
1770	26	3	59	26	8	25	14	13	2	29	50	53	3	25	12	14
1771	15	12	48	2	8	14	30	5	1	9	38	58	4	3	15	1
1772	3	21	36	39	8	3	45	57	11	17	27	3	4	11	17	48
1773	22	19	9	19	8	22	8	9	10	25	4	9	5	20	0	50
1774	12	3	57	55	8	11	24	1	9	4	52	14	5	28	3	37
1775	1	12	46	31	8	0	39	53	7	14	40	19	6	6	6	24
1776	19	10	19	12	8	19	2	5	6	20	17	25	7	14	49	25
1777	8	19	7	48	8	8	17	57	5	0	5	30	7	22	52	12
1778	27	16	40	28	8	26	40	9	4	5	42	36	9	1	35	13
1779	17	1	29	4	8	15	56	1	2	15	30	41	9	9	38	0
1780	5	10	17	40	8	5	11	53	0	25	18	46	9	17	40	47
1781	24	7	50	21	8	23	34	5	0	0	55	52	10	26	23	48
1782	13	16	38	57	8	12	49	58	10	10	43	57	11	4	26	35
1783	3	1	27	33	8	2	5	50	8	20	32	2	11	12	29	22
1784	20	23	0	13	8	20	28	3	9	26	9	8	0	21	12	23
1785	10	7	48	50	8	9	43	55	6	5	57	13	0	29	15	10
1786	29	5	21	30	8	28	6	7	5	11	34	19	2	7	58	12

TABLE II. *concluded. New Stile.*

Y. of Chr.	Mean New Moon in March.				Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's mean Diſt. from the Node.			
	D.	H.	M.	S.	s	°	′	″	s	°	′	″	s	°	′	″
1787	18	14	10	6	8	17	21	59	3	21	22	24	2	16	0	59
1788	6	22	58	42	8	6	37	51	2	1	10	29	2	24	3	46
1789	25	20	31	23	8	25	0	3	1	6	47	35	4	2	46	48
1790	15	5	19	59	8	14	15	55	11	16	35	40	4	10	49	35
1791	4	14	8	35	8	3	31	47	9	26	23	45	4	18	52	22
1792	22	11	41	15	8	21	53	59	9	2	0	52	5	27	35	24
1793	11	20	29	51	8	11	9	51	7	11	48	57	6	5	38	11
1794	30	18	2	32	8	29	32	3	6	17	26	4	7	14	21	13
1795	20	2	51	8	8	18	47	55	4	27	14	9	7	22	24	0
1796	8	11	39	44	8	8	3	47	3	7	2	14	8	0	26	47
1797	27	9	12	24	8	26	25	59	2	12	39	19	9	9	9	48
1798	16	18	1	1	8	15	41	51	0	22	27	25	9	17	12	35
1799	6	2	49	37	8	4	57	43	11	2	15	30	9	25	15	22
1800	25	0	22	17	8	23	19	55	10	7	52	36	11	3	58	24

TABLE III. *Mean Anomalies, and Sun's mean Diſtance from the Node, for* 13½ *mean Lunations.*

No.	Mean Lunations.				Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's mean Diſt. from the Node.			
	D.	H.	M.	S	s	°	′	″	s	°	′	″	s	°	′	″
1	29	12	44	3	0	29	6	19	0	25	49	0	1	0	40	14
2	59	1	28	6	1	28	12	39	1	21	38	1	2	1	20	28
3	88	14	12	9	2	27	18	58	2	17	27	1	3	2	0	42
4	118	2	56	12	3	26	25	17	3	13	16	2	4	2	40	56
5	147	15	40	15	4	25	31	37	4	9	5	2	5	3	21	10
6	177	4	14	18	5	24	37	56	5	4	54	3	6	4	1	24
7	206	17	8	21	6	23	44	15	6	0	43	3	7	4	41	38
8	236	5	52	24	7	22	50	35	6	26	32	3	8	5	21	52
9	265	18	36	27	8	21	56	54	7	22	21	4	9	6	2	6
10	295	7	20	30	9	21	3	14	8	18	10	4	10	6	42	20
11	324	20	4	33	10	20	9	33	9	13	59	5	11	7	22	34
12	354	8	48	36	11	19	15	52	10	9	48	5	0	8	2	47
13	383	21	32	40	0	18	22	12	11	5	37	6	1	8	43	1
½	14	18	22	[illegible]	0	14	33	10	6	12	54	30	0	15	20	7

TABLE

TABLE IV. *The Days of the Year, reckoned from the beginning of* March.

Days.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.	February.
1	1	32	62	93	123	154	185	215	246	276	307	338
2	2	33	63	94	124	155	186	216	247	277	308	339
3	3	34	64	95	125	156	187	217	248	278	309	340
4	4	35	65	96	126	157	188	218	249	279	310	341
5	5	36	66	97	127	158	189	219	250	280	311	342
6	6	37	67	98	128	159	190	220	251	281	312	343
7	7	38	68	99	129	160	191	221	252	282	313	344
8	8	39	69	100	130	161	192	222	253	283	314	345
9	9	40	70	101	131	162	193	223	254	284	315	346
10	10	41	71	102	132	163	194	224	255	285	316	347
11	11	42	72	103	133	164	195	225	256	286	317	348
12	12	43	73	104	134	165	196	226	257	287	318	349
13	13	44	74	105	135	166	197	227	258	288	319	350
14	14	45	75	106	136	167	198	228	259	289	320	351
15	15	46	76	107	137	168	199	229	260	290	321	352
16	16	47	77	108	138	169	200	230	261	291	322	353
17	17	48	78	109	139	170	201	231	262	292	323	354
18	18	49	79	110	140	171	202	232	263	293	324	355
19	19	50	80	111	141	172	203	233	264	294	325	356
20	20	51	81	112	142	173	204	234	265	295	326	357
21	21	52	82	113	143	174	205	235	266	296	327	358
22	22	53	83	114	144	175	206	236	267	297	328	359
23	23	54	84	115	145	176	207	237	268	298	329	360
24	24	55	85	116	146	177	208	238	269	299	330	361
25	25	56	86	117	147	178	209	239	270	300	331	362
26	26	57	87	118	148	179	210	240	271	301	332	363
27	27	58	88	119	149	180	211	241	272	302	333	364
28	28	59	89	120	150	181	212	242	273	303	334	365
29	29	60	90	121	151	182	213	243	274	304	335	366
30	30	61	91	122	152	183	214	244	275	305	336	
31	31		92		153	184		245		306	337	

TABLE V. *Mean Lunations from* 1 *to* 100000.

Lunat.	Days. Decimal Parts.	Days.	Hou.	M.	S.	Th.	Fo.
1	29.530590851080	= 29	12	44	3	2	58
2	59.061181702160	59	1	28	6	5	57
3	88.591772553240	88	14	12	9	8	55
4	118.122363404320	118	2	56	12	11	53
5	147.652954255401	147	15	40	15	14	52
6	177.183545106481	177	4	24	18	17	50
7	206.714135957561	206	17	8	21	20	48
8	236.244726808641	236	5	52	24	23	47
9	265.775317659722	265	18	36	27	26	45
10	295.305908851080	295	7	20	30	29	43
20	590.61181702160	590	14	41	0	59	26
30	885.91772553240	885	22	1	31	29	10
40	1181.22363404320	1181	5	22	1	58	53
50	1476.52954255401	1476	12	42	32	28	36
60	1771.83545106481	1771	20	3	2	58	19
70	2067.14135957561	2067	3	23	33	28	2
80	2362.44726808641	2362	10	44	3	57	46
90	2657.75317659722	2657	18	4	34	27	29
100	2953.059085108o	2953	1	25	4	57	12
200	5906.1181702160	5906	2	50	9	54	24
300	8859.1772553240	8859	4	15	14	51	36
400	11812.2363404320	11812	5	40	19	48	48
500	14765.2954255401	14765	7	5	24	46	0
600	17718.3545106481	17718	8	30	29	43	12
700	20671.4135957561	20671	9	55	34	40	24
800	23624.4726808641	23624	11	20	39	37	36
900	26577.5317659722	26577	12	45	44	34	48
1000	29530.590851080	29530	14	10	49	32	0
2000	59061.181702160	59061	4	21	39	4	0
3000	88591.772553140	88591	18	32	28	36	0
4000	118122.363404320	118122	8	43	18	8	0
5000	147652.954255401	147652	22	54	7	40	0
6000	177183.545106481	177183	13	4	57	12	0
7000	206714.135957561	206714	3	15	46	44	0
8000	236244.726801641	236244	17	26	36	16	0
9000	265775.317659722	265775	7	37	25	48	0
10000	295305.9085108o	295305	21	48	15	20	0
20000	590611.81702160	590611	19	36	30	40	0
30000	885917.72553240	885917	17	24	46	0	0
40000	1181223.63404320	1188223	15	13	1	20	0
50000	1476529.54255401	1476529	13	1	16	40	0
60000	1771835.45106481	1771835	10	49	32	0	0
70000	2067141.35957561	2067141	8	37	47	20	0
80000	2362447.26808641	2362447	6	25	2	40	0
90000	2657753.17659722	2657753	4	14	18	0	0
100000	2953959.0851080	2953059	2	2	33	20	0

TABLE VI. *The first mean New Moon, with the mean Anomalies of the Sun and Moon, and the Sun's mean Distance from the Ascending Node, next after complete Centuries of Julian years.*

Lunations.	Julian years.	First New Moon.				Sun's mean Anomaly.			Moon's mean Anomaly.			Sun from Node.		
		D.	H.	M.	S.	s	°	′	s	°	′	s	°	′
1237	100	4	8	10	52	0	3	21	8	15	22	4	19	27
2474	200	8	16	21	44	0	6	42	5	0	44	9	8	55
3711	300	13	0	32	37	0	10	3	1	16	6	1	28	22
4948	400	17	8	43	29	0	13	24	10	1	28	6	17	49
6185	500	21	16	54	21	0	16	46	6	16	50	11	7	16
7422	600	26	1	5	14	0	20	7	3	2	12	3	26	44
8658	700	0	20	32	3	11	24	22	10	21	45	7	15	31
9895	800	5	4	42	55	11	27	43	7	7	7	0	4	58
11132	900	9	12	53	47	0	1	4	3	22	29	4	24	25
12369	1000	13	21	4	40	0	4	25	0	7	51	9	13	53
13606	1100	18	5	15	32	0	7	46	8	23	13	2	3	20
14843	1200	22	13	26	24	0	11	7	5	8	35	6	22	47
16080	1300	26	21	37	16	0	14	28	1	23	57	11	12	15
17316	1400	1	17	4	6	11	18	43	9	13	30	3	1	2
18553	1500	6	1	14	58	11	22	4	5	28	52	7	20	29
19790	1600	10	9	25	50	11	25	25	2	14	14	0	9	56
21027	1700	14	17	36	42	11	28	46	10	29	36	4	29	23
22264	1800	19	1	47	35	0	2	8	7	14	58	9	18	51
23501	1900	23	9	58	27	0	5	29	4	0	20	2	8	18
24738	2000	27	18	9	19	0	8	50	0	15	42	6	27	45
25974	2100	2	13	36	8	11	13	5	8	5	15	10	16	32
27211	2200	6	21	47	1	11	16	26	4	20	37	3	6	0
28448	2300	11	5	57	53	11	19	47	1	5	59	7	25	27
29685	2400	15	14	8	45	11	23	8	9	21	21	0	14	54
30922	2500	19	22	19	38	11	26	29	6	6	43	5	4	22
32159	2600	24	6	30	30	11	29	50	2	22	4	9	23	49
33396	2700	28	14	41	22	0	3	11	11	7	26	2	13	16
34632	2800	3	10	8	11	11	7	26	6	26	59	6	2	3
35869	2900	7	18	19	3	11	10	47	3	12	21	10	21	30
37106	3000	12	2	29	56	11	14	8	11	27	43	3	10	58
38343	3100	16	10	40	48	11	17	30	8	13	5	8	0	25
39580	3200	20	18	51	40	11	20	51	4	28	27	0	19	52

TABLE

TABLE VI. *concluded.*

Lunations.	Julian years.	First New Moon. D.	H.	M.	S.	Sun's mean Anomaly. s	°	'	Moon's mean Anomaly. s	°	'	Sun's mean Dist. from Node. s	°	'
40817	3300	25	3	2	33	11	24	12	1	13	49	5	9	20
42054	3400	29	11	13	25	11	27	33	9	29	11	9	28	47
43290	3500	4	6	40	14	11	1	48	5	18	44	1	17	34
44527	3600	8	14	51	6	11	5	9	2	4	6	6	7	1
45764	3700	12	23	1	59	11	8	30	10	19	28	10	26	29
47001	3800	17	7	12	51	11	11	51	7	4	50	3	15	56
48238	3900	21	15	23	43	11	15	12	3	20	12	8	5	23
49475	4000	25	23	34	35	11	18	33	0	5	34	0	24	50
50711	4100	0	19	1	27	10	22	48	7	25	7	4	13	37
51948	4200	5	3	12	17	10	26	9	4	10	29	9	3	5
53185	4300	6	11	23	9	10	29	31	0	25	51	1	22	32
54422	4400	13	19	34	1	11	2	52	9	11	13	6	11	59
55659	4500	18	3	44	54	11	6	13	5	26	35	11	1	27
56896	4600	22	11	55	46	11	9	34	2	11	57	3	20	54
58133	4700	26	20	6	38	11	12	55	10	27	19	8	10	21
59369	4800	1	15	33	27	10	17	9	6	16	52	11	29	8
60606	4900	5	23	44	20	10	20	31	3	2	14	4	18	36
61843	5000	10	7	55	12	10	23	52	11	17	36	9	8	3
63080	5100	14	16	6	4	10	27	13	8	2	58	1	27	30
64317	5200	19	0	16	56	11	0	34	4	18	20	6	16	57
65354	5300	23	8	27	49	11	3	55	1	3	42	11	6	25
66791	5400	27	16	38	41	11	7	16	9	19	4	2	25	52
68028	5500	2	12	5	30	10	11	31	5	8	37	7	14	39
69265	5600	6	20	16	22	10	14	52	1	23	59	0	4	6
70502	5700	11	4	27	15	10	18	14	10	9	21	4	23	34
71739	5800	15	12	38	7	10	21	35	6	24	43	9	13	1
72976	5900	19	20	48	59	10	24	56	3	10	5	2	2	28
74212	6000	24	4	59	52	10	28	17	11	25	27	6	21	56

If Dr. *Pound*'s mean Lunation (which we have kept by in making these Tables) be added 74212 times to itself, the sum will amount to 6000 Julian years 24 days 4 hours 59 minutes 51 seconds 40 thirds; agreeing with the first part of the last line of this Table, within half a second.

TABLE VII. *The annual, or first Equation of the mean to the true Syzygy.*

Argument. Sun's mean Anomaly.

Subtract

Degrees.	0 Sign	1 Sign	2 Signs	3 Signs	4 Signs	5 Signs	Degrees.
	H. M. S.	H. M. S.	H. M. S.	H. M. S.	H. M. S.	H. M. S.	
0	0 0 0	2 3 12	3 35 0	4 10 53	3 39 30	2 7 45	30
1	0 4 18	2 6 55	3 37 10	4 10 57	3 37 19	2 3 55	29
2	0 8 35	2 10 36	3 39 18	4 10 55	3 35 6	2 0 1	28
3	0 12 51	2 14 14	3 41 23	4 10 49	3 32 50	1 56 5	27
4	0 17 8	2 17 52	3 43 26	4 10 39	3 30 30	1 52 6	26
5	0 21 24	2 21 27	3 45 25	4 10 24	3 28 5	1 48 4	25
6	0 25 39	2 25 9	3 47 19	4 10 4	3 25 35	1 41 1	24
7	0 28 55	2 28 29	3 49 7	4 9 39	3 23 0	1 39 56	23
8	0 34 11	2 31 57	3 50 50	4 9 10	3 20 20	1 35 49	22
9	0 38 26	2 35 22	3 52 29	4 8 37	3 17 35	1 31 41	21
10	0 42 39	2 38 44	3 54 4	4 7 59	3 14 49	1 27 31	20
11	0 46 52	2 42 3	3 55 35	4 7 16	3 11 59	1 23 19	19
12	0 51 4	2 45 18	3 57 2	4 6 29	3 9 6	1 19 5	18
13	0 55 17	2 48 30	3 58 27	4 5 37	3 6 10	1 14 49	17
14	0 59 27	2 51 40	3 59 49	4 4 41	3 3 10	1 10 33	16
15	1 3 36	2 54 48	3 1 7	4 3 40	3 0 7	1 6 15	15
16	1 7 45	2 57 53	4 2 18	4 2 35	2 57 0	1 1 56	14
17	1 11 53	3 0 54	4 3 23	4 1 26	2 53 49	0 57 36	13
18	1 16 0	3 3 51	4 4 22	4 0 12	2 50 36	0 53 15	12
19	1 20 6	3 6 45	4 5 18	3 58 52	2 47 18	0 48 52	11
20	1 24 10	3 9 36	4 6 10	3 57 27	2 43 57	0 44 28	10
21	1 28 12	3 12 24	4 6 58	3 55 59	2 40 33	0 40 2	9
22	1 32 12	3 15 9	4 7 41	3 54 26	2 37 6	0 35 36	8
23	1 36 10	3 17 51	4 8 21	3 52 49	2 33 35	0 31 10	7
24	1 40 6	3 20 30	4 8 57	3 51 9	2 30 2	0 26 44	6
25	1 44 1	3 23 5	4 9 29	3 49 26	2 26 26	0 22 17	5
26	1 47 54	3 25 36	4 9 55	3 47 38	2 22 47	0 17 50	4
27	1 51 46	3 28 3	4 10 16	3 45 44	2 19 5	0 13 23	3
28	1 55 37	3 30 26	4 10 33	3 43 45	2 15 20	0 8 56	2
29	1 59 26	3 32 45	4 10 45	3 41 40	2 11 35	0 4 29	1
30	2 3 12	3 35 0	4 10 53	3 39 30	2 7 45	0 0 0	0
Deg.	11 Signs	10 Signs	9 Signs	8 Signs	7 Signs	6 Signs	Deg.

Add

TABLE VIII. *Equation of the Moon's mean Anomaly.*

Argument. Sun's mean Anomaly.

Subtract

Degrees.	0 Sign ° ′ ″	1 Sign ° ′ ″	2 Signs ° ′ ″	3 Signs ° ′ ″	4 Signs ° ′ ″	5 Signs ° ′ ″	Degrees.
0	0 0 0	0 46 45	1 21 32	1 35 1	1 23 4	0 48 19	30
1	0 1 37	0 48 10	1 22 21	1 35 2	1 22 14	0 46 51	29
2	0 3 13	0 49 34	1 23 10	1 35 1	1 21 24	0 45 23	28
3	0 4 52	0 50 53	1 23 57	1 35 0	1 20 32	0 43 54	27
4	0 6 28	0 52 19	1 24 41	1 34 57	1 19 38	0 42 24	26
5	0 8 6	0 53 40	1 25 24	1 34 50	1 18 42	0 40 53	25
6	0 9 42	0 55 0	1 26 6	1 34 43	1 17 45	0 39 21	24
7	0 11 20	0 56 21	1 26 48	1 34 33	1 16 48	0 37 49	23
8	0 12 56	0 57 38	1 27 28	1 34 22	1 15 47	0 36 15	22
9	0 14 33	0 58 56	1 28 6	1 34 9	1 14 44	0 34 40	21
10	0 16 10	1 0 13	1 28 43	1 33 53	1 13 41	0 33 5	20
11	0 17 47	1 1 29	1 29 17	1 33 37	1 12 37	0 31 31	19
12	0 19 23	1 2 43	1 29 51	1 33 20	1 11 33	0 29 54	18
13	0 20 59	1 3 56	1 30 22	1 33 0	1 10 26	0 28 18	17
14	0 22 35	1 5 8	1 30 50	1 32 38	1 9 17	0 26 40	16
15	0 24 10	1 6 18	1 31 19	1 32 14	1 8 8	0 25 3	15
16	0 25 45	1 7 27	1 31 45	1 31 50	1 6 58	0 23 23	14
17	0 27 19	1 8 36	1 32 12	1 31 23	1 5 46	0 21 45	13
18	0 28 52	1 9 42	1 32 34	1 30 55	1 4 32	0 20 7	12
19	0 30 25	1 10 49	1 32 57	1 30 25	1 3 19	0 18 28	11
20	0 31 57	1 11 54	1 33 17	1 29 54	1 2 1	0 16 48	10
21	0 33 29	1 12 58	1 33 36	1 29 20	1 0 45	0 15 8	9
22	0 35 2	1 14 1	1 33 52	1 28 45	0 59 26	0 13 28	8
23	0 36 32	1 15 1	1 34 6	1 28 9	0 58 7	0 11 48	7
24	0 38 1	1 16 0	1 34 18	1 27 30	0 56 45	0 10 7	6
25	0 39 2	1 16 59	1 34 30	1 26 50	0 55 23	0 8 20	5
26	0 40 59	1 17 57	1 34 40	1 26 27	0 54 1	0 6 44	4
27	0 42 26	1 18 52	1 34 48	1 25 5	0 52 37	0 5 3	3
28	0 43 54	1 19 47	1 34 54	1 24 39	0 51 12	0 3 21	2
29	0 45 19	1 20 40	1 34 58	1 23 52	0 49 45	0 1 40	1
30	0 47 45	1 21 32	1 35 1	1 23 4	0 48 19	0 0 0	0
Deg.	11 Signs	10 Signs	9 Signs	8 Signs	7 Signs	6 Signs	Deg.

Add

TABLE IX. *The second Equation of the mean to the true Syzygy.*

Argument. Moon's equated Anomaly.

Add

Degrees.	0 Sign			1 Sign			2 Signs			3 Signs			4 Signs			5 Signs			Degrees.
	H.	M.	S	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.	
0	0	0	0	5	12	48	8	47	8	9	46	44	8	8	59	4	34	33	30
1	0	10	58	5	21	56	8	51	45	9	45	3	8	3	12	4	26	1	29
2	0	21	56	5	30	57	8	56	10	9	45	12	7	57	23	4	17	25	28
3	0	32	54	5	39	51	9	0	25	9	44	11	7	51	33	4	8	47	27
4	0	42	52	5	48	37	9	4	31	9	42	59	7	45	46	4	0	7	26
5	0	54	50	5	57	17	9	8	25	9	41	36	7	39	46	3	51	23	25
6	1	5	48	6	5	51	9	12	9	9	40	3	7	33	36	3	42	32	24
7	1	16	46	6	14	19	9	15	43	9	38	19	7	27	22	3	33	38	23
8	1	27	44	6	22	41	9	19	5	9	36	24	7	21	2	3	24	42	22
9	1	38	40	6	30	57	9	22	14	9	34	18	7	14	30	3	15	44	21
10	1	49	33	6	39	4	9	25	12	9	32	1	7	7	50	3	6	45	20
11	2	0	23	6	47	0	9	27	58	9	29	33	7	1	2	2	57	43	19
12	2	11	10	6	54	46	9	30	32	9	26	54	6	54	8	2	48	39	18
13	2	21	54	7	2	24	9	32	58	9	24	4	6	47	9	2	39	34	17
14	2	32	34	7	9	52	9	35	12	9	21	3	6	40	6	2	30	28	16
15	2	43	9	7	17	9	9	37	14	9	17	51	6	32	56	2	21	19	15
16	2	53	38	7	24	19	9	39	8	9	14	28	6	25	40	2	12	8	14
17	3	4	3	7	31	18	9	40	51	9	10	54	6	18	18	2	2	53	13
18	3	14	24	7	38	9	9	42	21	9	7	9	6	10	49	1	53	36	12
19	3	24	42	7	44	51	9	43	42	9	3	13	6	3	16	1	44	16	11
20	3	34	58	7	51	24	9	44	53	8	59	6	5	55	38	1	34	54	10
21	3	45	11	7	57	45	9	45	52	8	54	50	5	47	54	1	25	31	9
22	3	55	21	8	3	56	9	46	38	8	50	24	5	40	4	1	16	7	8
23	4	5	26	8	9	57	9	47	13	8	45	48	5	32	9	1	6	41	7
24	4	25	26	8	15	46	9	47	36	8	41	2	5	24	9	0	57	13	6
25	4	25	20	8	21	24	9	47	49	8	36	6	5	16	5	0	47	44	5
26	4	35	6	8	26	53	9	47	54	8	31	0	5	7	56	0	38	13	4
27	4	44	42	8	32	11	9	47	46	8	25	44	4	59	42	0	28	41	3
28	4	54	11	8	37	19	9	47	33	8	20	18	4	51	15	0	19	[illegible]	2
29	5	3	33	8	42	18	9	47	14	8	14	33	4	43	2	0	9	34	1
30	5	12	48	8	47	8	9	46	44	8	8	59	4	34	33	0	0	0	0
Deg.	11 Signs			10 Signs			9 Signs			8 Signs			7 Signs			6 Signs			Deg.

Subtract

TABLE

TABLE X. *The third Equation of the mean to the true Syzygy.*

Argument. Sun's Anomaly—Moon's Anomaly.

Degrees.	0 / 6 Signs. Sub. Add M.	S.	1 / 7 Signs. Sub. Add M.	S.	2 / 8 Signs. Sub. Add M.	S.	Degrees.
0	0	0	2	22	4	12	30
1	0	5	2	26	4	15	29
2	0	10	2	30	4	18	28
3	0	15	2	34	4	21	27
4	0	20	2	38	4	24	26
5	0	25	2	42	4	27	25
6	0	30	2	46	4	30	24
7	0	35	2	50	4	32	23
8	0	40	2	54	4	34	22
9	0	45	2	58	4	36	21
10	0	50	3	2	4	38	20
11	0	55	3	6	4	40	19
12	1	0	3	10	4	42	18
13	1	5	3	14	4	44	17
14	1	10	3	18	4	46	16
15	1	15	3	22	4	48	15
16	1	20	3	26	4	50	14
17	1	25	3	30	4	51	13
18	1	30	3	34	4	52	12
19	1	35	3	38	4	53	11
20	1	40	3	42	4	54	10
21	1	45	3	45	4	55	9
22	1	49	3	48	4	56	8
23	1	52	3	51	4	57	7
24	1	56	3	54	4	57	6
25	2	0	3	57	4	57	5
26	2	4	4	0	4	58	4
27	2	9	4	3	4	58	3
28	2	13	4	6	4	58	2
29	2	18	4	9	4	58	1
30	2	22	4	12	4	58	0
Degrees.	Signs. 5 / 11 Sub. Add		Signs. 4 / 10 Sub. Add		Signs. 3 / 9 Sub. Add		Degrees.

TABLE XI. *The fourth Equation of the mean to the true Syzygy.*

Argument. Sun's mean Distance from the Node.

Add

Degrees.	0 / 6 Sig. M.	S.	1 / 7 Sig. M.	S.	2 / 8 Sig. M.	S.	Degrees.
0	0	0	1	22	1	22	30
1	0	4	1	23	1	21	29
2	0	7	1	24	1	20	28
3	0	10	1	25	1	18	27
4	0	13	1	26	1	16	26
5	0	16	1	27	1	14	25
6	0	20	1	28	1	12	24
7	0	23	1	29	1	10	23
8	0	26	1	30	1	8	22
9	0	29	1	31	1	6	21
10	0	32	1	32	1	3	20
11	0	35	1	33	1	0	19
12	0	38	1	33	0	57	18
13	0	41	1	34	0	54	17
14	0	44	1	34	0	51	16
15	0	47	1	34	0	49	15
16	0	50	1	34	0	45	14
17	0	52	1	34	0	41	13
18	0	54	1	34	0	37	12
19	0	57	1	33	0	34	11
20	1	0	1	33	0	31	10
21	1	2	1	32	0	28	9
22	1	5	1	31	0	25	8
23	1	8	1	30	0	22	7
24	1	10	1	29	0	19	6
25	1	12	1	28	0	16	5
26	1	14	1	27	0	13	4
27	1	16	1	26	0	10	3
28	1	18	1	25	0	6	2
29	1	20	1	24	0	3	1
30	1	22	1	22	0	0	0
Deg.	5 / 11 Sig.		4 / 10 Sig.		3 / 9 Sig		Deg.

Subtract

TABLE XII. *The Sun's mean Longitude, Motion, and Anomaly: Old Stile.*

Years beginning	Sun's mean Longitude.				Sun's mean Anomaly.		
	s	°	'	"	s	°	'
1	9	7	53	10	6	28	48
201	9	9	23	50	6	26	57
301	9	10	9	10	6	26	1
401	9	10	54	30	6	25	5
501	9	11	39	50	6	24	9
1001	9	15	26	30	6	19	32
1101	9	16	11	50	6	18	36
1201	9	16	57	10	6	17	40
1301	9	17	42	30	6	16	44
1401	9	18	27	50	6	15	49
1501	9	19	13	10	6	14	53
1601	9	19	58	30	6	13	57
1701	9	20	43	50	6	13	1
1801	9	21	29	10	6	12	6

Years compleat.	Sun's mean Motion.				Sun's mean Anomaly.		
	s	°	'	"	s	°	'
1	11	29	45	40	11	29	45
2	11	29	31	20	11	29	29
3	11	29	17	0	11	29	14
4	0	0	1	49	11	29	58
5	11	29	47	29	11	29	42
6	11	29	33	9	11	29	27
7	11	29	18	49	11	29	11
8	0	0	3	38	11	29	55
9	11	29	49	18	11	29	40
10	11	29	34	58	11	29	24
11	11	29	20	38	11	29	9
12	0	0	5	26	11	29	53
13	11	29	51	7	11	29	37
14	11	29	36	47	11	29	22
15	11	29	22	27	11	29	7
16	0	0	7	15	11	29	50
17	11	29	52	55	11	29	35
18	11	29	38	35	11	29	20

Years compleat	Sun's mean Motion.				Sun's mean Anomaly.		
	s	°	'	"	s	°	'
19	11	29	24	16	11	29	4
20	0	0	9	4	11	29	48
40	0	0	18	8	11	29	37
60	0	0	27	12	11	29	26
80	0	0	36	16	11	29	15
100	0	0	45	20	11	29	4
200	0	1	30	40	11	28	8
300	0	2	16	0	11	27	12
400	0	3	1	20	11	26	16
500	0	3	46	40	11	25	21
600	0	4	32	0	11	24	25
700	0	5	17	20	11	23	29
800	0	6	2	40	11	22	33
900	0	6	48	0	11	21	37
1000	0	7	33	20	11	20	41
2000	0	15	6	40	11	11	22
3000	0	22	40	0	11	2	3
4000	1	0	13	20	10	22	44
5000	1	7	46	40	10	13	25
6000	1	15	20	0	10	4	6

Months.	Sun's mean Motion.				Sun's mean Anomaly.		
	s	°	'	"	s	°	'
Jan.	0	0	0	0	0	0	0
Feb.	1	0	33	18	1	0	33
Mar.	1	28	9	11	1	28	9
Apr.	2	28	42	30	2	28	42
May	3	28	16	40	3	28	17
June	4	28	49	58	4	28	50
July	5	28	24	8	5	28	24
Aug.	6	28	57	26	6	28	57
Sept.	7	29	30	44	7	29	30
Oct.	8	29	4	54	8	29	4
Nov.	9	29	38	12	9	29	37
Dec.	10	29	12	22	10	29	11

TABLE XII. *concluded.*

Days.	Sun's mean Motion and Anomaly.					Sun's mean Motion and Anomaly.			Sun's mean Dist. from Node.				Sun's mean Motion and Anomaly.			Sun's mean Dist. from Node.		
	s	°	'	"	H M S	° ' "	' " '''	" ''' ''''	° ' "	' " '''	" ''' ''''	H M S	° ' "	' " '''	" ''' ''''	° ' "	' " '''	" ''' ''''
1	0	0	59	8														
2	0	1	58	17	1	0	2	28	0	2	36	31	1	16	23	1	20	30
3	0	2	57	25	2	0	4	56	0	5	12	32	1	18	51	1	23	6
4	0	3	56	33	3	0	7	24	0	7	48	33	1	21	19	1	25	42
5	0	4	55	42	4	0	9	51	0	10	23	34	1	23	47	1	28	18
6	0	5	54	50	5	0	12	19	0	12	59	35	1	26	15	1	30	54
7	0	6	53	58	6	0	14	47	0	15	35	36	1	28	42	1	33	29
8	0	7	53	7	7	0	17	15	0	18	11	37	1	31	10	1	36	5
9	0	8	52	15	8	0	19	43	0	20	47	38	1	33	38	1	38	40
10	0	9	51	23	9	0	22	11	0	23	23	39	1	36	6	1	41	16
11	0	10	50	32	10	0	24	38	0	25	58	40	1	38	34	1	43	52
12	0	11	49	40	11	0	27	6	0	28	34	41	1	41	2	1	46	28
13	0	12	48	48	12	0	29	34	0	31	10	42	1	43	30	1	49	4
14	0	13	47	57	13	0	32	2	0	33	45	43	1	45	57	1	51	39
15	0	14	47	5	14	0	34	30	0	36	21	44	1	48	25	1	54	15
16	0	15	46	13	15	0	36	58	0	38	57	45	1	50	53	1	55	51
17	0	16	45	22	16	0	39	26	0	41	33	46	1	53	21	1	59	27
18	0	17	44	30	17	0	41	53	0	44	8	47	1	55	49	2	2	3
19	0	18	43	38	18	0	44	21	0	46	44	48	1	58	17	2	4	39
20	0	19	42	47	19	0	46	49	0	49	20	49	2	0	44	2	7	13
21	0	20	41	55	20	0	49	17	0	51	56	50	2	3	12	2	9	50
22	0	21	41	3	21	0	51	45	0	54	32	51	2	5	40	2	12	25
23	0	22	40	12	22	0	54	13	0	57	8	52	2	8	8	2	15	2
24	0	23	39	20	23	0	56	40	0	59	43	53	2	10	36	2	17	38
25	0	24	38	28	24	0	59	8	1	2	19	54	2	13	4	2	20	14
26	0	25	37	37	25	1	1	36	1	4	55	55	2	15	32	2	22	50
27	0	26	36	45	26	1	4	4	1	7	31	56	2	17	59	2	25	26
28	0	27	35	53	27	1	6	32	1	10	7	57	2	20	27	2	28	2
29	0	28	35	2	28	1	9	0	1	12	43	58	2	22	55	2	30	38
30	0	29	34	10	29	1	11	28	1	15	19	59	2	25	23	2	33	14
31	1	30	33	18	30	1	13	55	1	17	55	60	2	27	51	2	35	50

In Leap years, after *February*, add one day, and one day's motion.

TABLE

TABLE XIII. *Equation of the Sun's Center, or the difference between his mean and true Place.*

Argument. Sun's mean Anomaly.

Subtract

Degrees.	0 Sign.	1 Sign.	2 Signs.	3 Signs.	4 Signs.	5 Signs.	Degrees.
	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
0	0 0 0	0 56 47	1 39 6	1 55 37	1 41 12	0 58 53	30
1	0 1 59	0 58 30	1 40 7	1 55 39	1 40 12	0 57 7	29
2	0 3 57	1 0 12	1 41 6	1 55 38	1 39 10	0 55 19	28
3	0 5 56	1 1 53	1 42 3	1 55 36	1 38 6	0 53 30	27
4	0 7 54	1 3 33	1 42 59	1 55 31	1 37 0	0 51 40	26
5	0 9 52	1 5 12	1 43 52	1 55 24	1 35 52	0 49 49	25
6	0 11 50	1 6 50	1 44 44	1 55 15	1 34 43	0 47 57	24
7	0 13 48	1 8 27	1 45 34	1 55 3	1 33 32	0 46 5	23
8	0 15 46	1 10 2	1 46 22	1 54 50	1 32 19	0 44 11	22
9	0 17 43	1 11 36	1 47 8	1 54 35	1 31 4	0 42 16	21
10	0 19 40	1 13 9	1 47 53	1 54 17	1 29 47	0 40 21	20
11	0 21 37	1 14 41	1 48 35	1 53 57	1 28 29	0 38 25	19
12	0 23 33	1 16 11	1 49 15	1 53 36	1 27 9	0 36 28	18
13	0 25 29	1 17 40	1 49 54	1 53 12	1 25 48	0 34 30	17
14	0 27 25	1 19 8	1 50 30	1 52 46	1 24 25	0 32 32	16
15	0 29 20	1 20 34	1 51 5	1 52 18	1 23 0	0 30 33	15
16	0 31 15	1 21 59	1 51 37	1 51 48	1 21 34	0 28 33	14
17	0 33 9	1 23 22	1 52 8	1 51 15	1 20 6	0 26 33	13
18	0 35 2	1 24 44	1 52 36	1 50 41	1 18 36	0 24 33	12
19	0 36 55	1 26 5	1 53 3	1 50 5	1 17 5	0 22 32	11
20	0 38 47	1 27 24	1 53 27	1 49 26	1 15 33	0 20 30	10
21	0 40 39	1 28 41	1 53 50	1 48 46	1 13 59	0 18 28	9
22	0 42 30	1 29 57	1 54 10	1 48 3	1 12 24	0 16 26	8
23	0 44 20	1 31 11	1 54 28	1 47 19	1 10 47	0 14 24	7
24	0 46 9	1 32 25	1 54 44	1 46 32	1 9 9	0 12 21	6
25	0 47 57	1 33 35	1 54 58	1 45 44	1 7 29	0 10 18	5
26	0 49 45	1 34 45	1 55 10	1 44 53	1 5 49	0 8 14	4
27	0 51 32	1 35 53	1 55 20	1 44 1	1 4 7	0 6 11	3
28	0 53 18	1 36 59	1 55 28	1 43 7	1 2 24	0 4 7	2
29	0 55 3	1 38 3	1 55 34	1 42 10	1 0 39	0 2 4	1
30	0 56 47	1 39 6	1 55 37	1 41 12	0 58 53	0 0 0	0
Deg.	11 Signs.	10 Signs.	9 Signs.	8 Signs.	7 Signs.	6 Signs.	Deg.

Add

TABLE

TABLE XIV. *The Sun's Declination.*

Argument. Sun's true Place.

Degrees.	Signs. 0 N. 6 S. °	′	Signs. 1 N. 7 S. °	′	Signs. 2 N. 8 S. °	′	Degrees.
0	0	0	11	30	20	11	30
1	0	24	11	51	20	24	29
2	0	48	12	11	20	36	28
3	1	12	12	32	20	48	27
4	1	36	12	53	20	59	26
5	1	59	13	13	21	10	25
6	2	23	13	33	21	21	24
7	2	47	13	53	21	31	23
8	3	11	14	12	21	41	22
9	3	34	14	31	21	50	21
10	3	58	14	50	21	59	20
11	4	22	15	9	22	8	19
12	4	45	15	28	22	16	18
13	5	9	15	46	22	24	17
14	5	32	16	4	22	31	16
15	5	55	16	22	22	38	15
16	6	18	16	39	22	45	14
17	6	41	16	57	22	51	13
18	7	4	17	14	22	56	12
19	7	27	17	30	23	2	11
20	7	50	17	46	23	6	10
21	8	13	18	2	23	11	9
22	8	35	18	18	23	14	8
23	9	57	18	33	23	18	7
24	9	20	18	48	23	21	6
25	9	42	19	3	23	21	5
26	10	4	19	17	23	25	4
27	10	25	19	31	23	27	3
28	10	47	19	45	23	28	2
29	11	8	19	58	23	29	1
30	11	30	20	11	23	29	0
Degrees.	Signs. 11 S. 5 N.		Signs. 10 S. 4 N.		Signs. 9 S. 3 N.		Degrees.

TABLE XV. *Equation of the Sun's mean Distance from the Node.*

Argument. Sun's mean Anomaly.

Subtract

Degrees.	0 Sign. °	′	1 Sign. °	′	2 Signs. °	′	3 Signs. °	′	4 Signs. °	′	5 Signs. °	′	Degrees.
0	0	0	1	2	1	47	2	5	1	50	1	4	30
1	0	2	1	4	1	48	2	5	1	48	1	2	29
2	0	4	1	6	1	49	2	5	1	47	1	0	28
3	0	6	1	8	1	50	2	5	1	46	0	58	27
4	0	9	1	10	1	51	2	5	1	45	0	56	26
5	0	11	1	12	1	52	2	5	1	44	0	54	25
6	0	13	1	14	1	53	2	5	1	43	0	52	24
7	0	15	1	16	1	54	2	4	1	41	0	50	23
8	0	17	1	17	1	55	2	4	1	40	0	48	22
9	0	19	1	18	1	56	2	4	1	39	0	46	21
10	0	21	1	19	1	57	2	4	1	37	0	44	20
11	0	23	1	21	1	58	2	3	1	36	0	42	19
12	0	25	1	22	1	58	2	3	1	34	0	40	18
13	0	28	1	24	1	59	2	3	1	33	0	37	17
14	0	30	1	26	2	0	2	2	1	31	0	35	16
15	0	32	1	27	2	0	2	2	1	30	0	33	15
16	0	34	1	28	2	1	2	1	1	28	0	31	14
17	0	36	1	30	2	1	2	1	1	27	0	29	13
18	0	38	1	31	2	2	2	0	1	25	0	27	12
19	0	40	1	34	2	2	2	0	1	24	0	24	11
20	0	42	1	35	2	3	1	59	1	23	0	22	10
21	0	44	1	36	2	3	1	59	1	21	0	20	9
22	0	46	1	37	2	4	1	58	1	19	0	18	8
23	0	48	1	39	2	4	1	57	1	17	0	16	7
24	0	50	1	40	2	4	1	56	1	15	0	13	6
25	0	52	1	41	2	4	1	55	1	13	0	11	5
26	0	54	1	43	2	5	1	54	1	11	0	9	4
27	0	56	1	44	2	5	1	53	1	9	0	7	3
28	0	58	1	45	2	5	1	52	1	8	0	5	2
29	1	0	1	46	2	5	1	51	1	6	0	3	1
30	1	2	1	47	2	5	1	50	1	4	0	0	0
Deg.	11 Signs.		10 Signs.		9 Signs.		8 Signs.		7 Signs.		6 Sign		Deg.

Add

TABLE XVI. *The Moon's Latitude in Eclipses.*

Argument. Moon's equated Distance from the Node.

0 Signs. *North Ascending.*				
6 Signs. *South Descending.*				
°	°	'	''	°
0	0	0	0	30
1	0	5	15	29
2	0	10	30	28
3	0	15	45	27
4	0	20	59	26
5	0	26	13	25
6	0	31	26	24
7	0	36	39	23
8	0	41	51	22
9	0	47	22	21
10	0	52	13	20
11	0	57	23	19
12	1	2	31	18
13	1	7	38	17
14	1	12	44	16
15	1	17	49	15
16	1	22	52	14
17	1	27	53	13
18	1	32	52	12
19	1	37	49	11
5 Signs. *North Descending.*				
11 Signs. *South Ascending.*				

This Table shews the Moon's Latitude a little beyond the utmost Limits of Eclipses.

TABLE XVII. *The Moon's horizontal Parallax, with the Semidiameters and true Horary Motions of the Sun and Moon, to every sixth Degree of their mean Anomalies, the Quantities for the intermediate Degrees being easily proportioned by Sight.*

Anomaly of Sun and Moon.		Moon's horizont. Parallax.		Sun's Semidiameter.		Moon's Semidiameter.		Moon's Horary Motion.		Sun's Horary Motion.		Anomaly of Sun and Moon.	
s	°	'	''	'	''	'	''	'	''	'	''	s	°
0	0	54	29	15	50	14	54	30	10	2	23	12	0
	6	54	31	15	50	14	55	30	12	2	23		24
	12	54	34	15	50	14	56	30	15	2	23		18
	18	54	40	15	51	14	57	30	19	2	23		12
	24	54	47	15	51	14	58	30	26	2	23		6
1	0	54	56	15	52	14	59	30	34	2	24	11	0
	6	55	6	15	53	15	1	30	44	2	24		24
	12	55	17	15	54	15	4	30	55	2	24		18
	18	55	29	15	55	15	8	31	9	2	24		12
	24	55	42	15	56	15	12	31	23	2	25		6
2	0	55	56	15	58	15	17	31	40	2	25	10	0
	6	56	12	15	59	15	22	31	56	2	26		24
	12	56	29	16	1	15	26	32	17	2	27		18
	18	56	48	16	2	15	30	32	39	2	27		12
	24	57	8	16	[illegible]	15	36	33	11	2	28		6
3	0	57	30	16	6	15	41	33	23	2	28	9	0
	6	57	52	16	8	15	46	33	47	2	29		24
	12	58	12	16	10	15	52	34	11	2	29		18
	18	58	31	16	11	15	58	34	34	2	29		12
	24	58	49	16	13	16	3	34	58	2	30		6
4	0	59	6	16	14	16	9	35	22	2	30	8	0
	6	59	21	16	15	16	14	35	45	2	31		24
	12	59	35	16	17	16	19	36	0	2	31		18
	18	59	48	16	19	16	24	36	20	2	32		12
	24	60	0	16	20	16	28	36	40	2	32		6
5	0	60	11	16	21	16	31	37	0	2	32	7	0
	6	60	21	16	21	16	32	37	10	2	33		24
	12	60	30	16	22	16	37	37	19	2	33		18
	18	60	38	16	22	16	38	37	28	2	33		12
	24	60	45	16	23	16	39	37	36	2	33		6
6	0	60	45	16	23	16	39	37	40	2	33	6	0

To calculate the true time of New or Full Moon.

PRECEPT I. If the required time be within the limits of the 18th century, write out the mean time of New Moon in *March*, for the propofed year, from Table I. in the Old Stile, or from Table II. in the New; together with the mean Anomalies of the Sun and Moon, and the Sun's mean Diftance from the Moon's afcending Node.—If you want the time of Full Moon in *March*, add the half Lunation at the foot of Table III. with its Anomalies, &c. to the former numbers, if the New Moon falls before the 15th of *March*; but if it falls after, fubtract the half Lunation, with the Anomalies, &c. belonging to it, from the former numbers, and write down the refpective fums or remainders.

II. In thefe additions or fubtractions, obferve, that 60 feconds make a minute, 60 minutes make a degree, 30 degrees make a fign, and 12 figns make a circle. When you exceed 12 figns in addition, reject 12, and fet down the remainder.—When the number of figns to be fubtracted is greater than the number you fubtract from, add 12 figns to the leffer number, and then you will have a remainder to fet down.—In the Tables, figns are marked thus^s, degrees thus^o, minutes thus$'$, and feconds thus$''$.

III. When the required New or Full Moon is in any given month after *March*, write out as many Lunations, with their Anomalies, and the Sun's diftance from the Node, from Table III. as the given month is after *March*; fetting them in order below the numbers taken out for *March*.

IV. Add all thefe together, and they will give the mean time of the required New or Full Moon, with the Mean Anomalies and Sun's mean diftance from the afcending Node, which are the Arguments for finding the proper Equations.

V. With

V. With the number of days added together, enter Table IV. under the given month; and againſt that number you have the day of mean New or Full Moon in the left hand column, which ſet before the hours, minutes, and ſeconds, already found.

But (as it will ſometimes happen) if the ſaid number of days fall ſhort of any in the column under the given month, add one Lunation and its Anomalies, &c. (from Table III.) to the foreſaid ſums, and then you will have a new ſum of days wherewith to enter Table IV. under the given month, where you are ſure to find it the ſecond time, if the firſt falls ſhort.

VI. With the ſigns and degrees of the Sun's Anomaly, enter Table VII. and therewith take out the annual or firſt Equation for reducing the mean Syzygy to the true; taking care to make proportions in the Table for the odd minutes and ſeconds of Anomaly, as the Table gives the Equation only to whole degrees.

Obſerve, in this and every other caſe of finding Equations, that if the ſigns are at the head of the Table, their degrees are at the left hand, and are reckoned downward; but if the ſigns are at the foot of the Table, their degrees are at the right hand, and are counted upward; the equation being in the body of the Table, under or over the ſigns, in a collateral line with the degrees.—The titles *Add* or *Subtract* at the head or foot of the Tables where the ſigns are found, ſhew whether the Equation is to be added to the mean time of New or Full Moon, or to be ſubtracted from it. In this Table, the Equation is to be ſubtracted if the ſigns of the Sun's Anomaly are found at the head of the Table; but it is to be added, if the ſigns are at the foot.

VII. With the ſigns and degrees of the Sun's mean Anomaly, enter Table VIII. and take out the Equation of the Moon's mean Anomaly; ſubtract this Equation from her mean Anomaly, if the signs of the Sun's Anomaly be at the head of the Table, but add it if they are at the foot; the result will be the Moon's equated Anomaly, with which enter Table IX, and take out the second Equation for reducing the mean to the true time of New or Full Moon; adding this Equation, if the signs of the Moon's Anomaly are at the head of the Table, but subtracting it if they are at the foot, and the result will give you the mean time of the required New or Full Moon twice equated, which will be sufficiently near for common almanacks.—But when you want to calculate an Eclipse, the following Equations must be used: thus,

VIII. Subtract the Moon's equated Anomaly from the Sun's mean Anomaly, and with the remainder in signs and degrees, enter Table X, and take out the third Equation, applying it to the former equated time, as the titles *Add* or *Subtract* do direct.

IX. With the Sun's mean distance from the ascending Node enter Table XI, and take out the Equation answering to that argument, adding it to, or subtracting it from, the former equated time, as the titles direct, and the result will give the time of New or Full Moon, agreeing with well regulated clocks or watches, very near the truth. But, to make it agree with the solar, or apparent time, apply the Equation of natural days, found in the Tables (from page 163 to page 175) as it is Leap-year, or the first, second, or third after.

The method of calculating the time of any New or full Moon without the limits of the 18th century, will be shown further on. And a few Examples, compared with the Precepts, will make the whole work plain.

N. B. The Tables begin the day at noon, and reckon forward from thence to the noon following.—Thus, March the 31st, at 22 h. 30 min. 25 sec. of tabular time, is *April* 1st (in common reckoning) at 30 min. 25 sec. after 10 o'clock in the morning.

EXAM-

EXAMPLE I.

Required the true time of New Moon in April 1764, *New Stile?*

By the Precepts,	New Moon.	Sun's Anom.	Moon's Anom.	Sun fro. Node.
	D. H. M. S.	s ° ′ ″	s ° ′ ″	s ° ′ ″
March 1764,	2 8 55 36	8 2 20 0	10 13 35 21	11 4 54 48
Add 1 Lunation,	29 12 44 3	0 29 6 19	0 25 49 0	1 0 40 14
Mean New Moon,	31 22 39 39	9 1 26 19	11 9 24 21	0 5 35 2
First Equation,	+ 4 10 40	11 10 59 18	+ 1 34 57	
Time once equated,	32 1 50 19	9 20 27 1	11 10 59 18	Sun fro. Node, and Arg. 4th equation.
Second Equation,	— 3 24 49	Arg. 3d equat.	Arg. 2d equat.	
Time twice equat.	31 22 25 30			
Third Equation,	+ 4 37			
Time thrice equat.	31 22 30 7			
Fourth Equation,	+ 18			
True New Moon,	31 22 30 25			
Equation of days,	— 3 48			
Apparent time,	31 22 26 37			

So the mean time is 22 h. 30 min. 25 sec. after the Noon of the 31st *March*; that is, *April* 1st, at 30 min. 25 sec. after X in the morning, But the apparent time is 26 min. 37 sec. after X in the morning.

EXAM-

EXAMPLE II.

Qu. *The true mean time of Full Moon in* May 1762, *Old Stile?*

By the Precepts.	New Moon.	Sun's Anom.	Moon's Anom.	Sun fro. Node.
	D. H. M. S.	s ° ′ ″	s ° ′ ″	s ° ′ ″
March 1762,	24 15 18 24	8 23 48 16	1 23 59 11	10 18 49 14
Add 2 Lunations,	59 1 28 6	1 28 12 39	1 21 38 1	2 1 20 28
New Moon, *May*,	22 16 46 30	10 22 0 55	3 15 37 12	0 20 9 42
Sub. ½ Lunation,	14 18 22 2	0 14 33 10	6 12 54 30	0 15 20 7
Full Moon, *May*,	7 22 24 28	10 7 27 45	9 2 42 42	0 4 49 35
Firſt Equation,	+ 3 16 36	9 3 57 15	+ 1 14 33	Sun fro. Node, and Arg. 4th equation.
Time once equat.	8 1 41 4	1 3 30 30	9 3 57 15	
Second Equation,	— 9 47 53	Arg. 3d equat.	Arg. 2d equat.	
Time twice equat.	7 15 53 11			
Third Equation,	— 2 36			
Time thrice equat.	7 15 50 35			
Fourth Equation,	+ 15			
The Full Moon,	7 15 50 50			

Anſ. *May* 7th at 15 h. 50 m. 50 ſec. paſt noon, viz. *May* 8th at III h. 50 min. 50 ſec. in the morning.

To calculate the time of New and Full Moon in a given year and month of any particular century between the Chriſtian Æra and the 18th century.

Precept I. Find a year of the ſame number in the 18th century with that of the year in the century propoſed, and take out the mean Time of New Moon in *March*, Old Stile, for that year, with the mean Anomalies and Sun's mean Diſtance from the Node at that time, as already taught.

II. Take as many complete centuries of years from Table VI. as, when ſubtracted from the abovesaid year in the 18th century, will anſwer to the given year; and take out the firſt mean New Moon and its Anomalies, &c. be-

 longing

longing to the ſaid centuries, and ſet them below thoſe taken out for *March* in the 18th century.

III. Subtract the numbers belonging to theſe centuries, from thoſe of the 18th century, and the remainders will be the mean Time and Anomalies, &c. of New Moon in *March*, in the given year of the century propoſed.—Then, work in all reſpects for the true time of New or Full Moon, as ſhewn in the above Precepts and Examples.

IV. If the days annexed to theſe centuries exceed the number of days from the beginning of *March* taken out in the 18th century, add a Lunation and its Anomalies, &c. from Table III. to the Time and Anomalies of New Moon, in *March*, and then proceed in all reſpects as above.—This circumſtance happens in Example V.

EXAMPLE III.

Required the true mean time of Full Moon in April, *Old Stile,* A.D. 30?

From 1730 ſubtract 1700 (or 17 centuries) and there remains 30.

By the Precepts.	New Moon.	Sun's Anom.	Moon's Anom.	Sun fro. Node.
	D. H. M. S.	s ° ′ ″	s ° ′ ″	s ° ′ ″
March 1730,	7 12 34 16	8 18 4 31	9 0 32 17	1 23 17 16
Add ½ Lunation,	14 18 22 2	0 14 33 10	6 12 54 30	0 15 20 7
Full Moon,	22 6 56 18	9 2 37 41	3 13 26 47	2 8 37 23
1700 years ſubtr.	14 17 36 42	11 28 46 0	10 29 36 0	4 29 23 0
Full ☽ *Mar.* A D. 30	7 13 19 36	9 3 51 41	4 13 50 47	9 9 14 23
Add 1 Lunation,	29 12 44 3	0 29 6 19	0 25 49 0	1 0 40 14
Full Moon, *April*,	6 2 3 39	10 2 58 0	5 9 39 47	10 9 54 37
Firſt Equation,	+ 3 28 4	5 10 58 40	+ 1 18 53	Sun fro. Node,
Time once equat.	6 5 31 43	4 21 59 20	5 10 58 40	and Arg. 4th
Second Equation,	+ 2 57 55	Arg. 3d equat.	Arg. 2d equat.	equation.
Time twice equat.	6 8 29 38			
Third Equation,	— 2 54			
Time thrice equat.	6 8 26 44			
Fourth Equation,	— 1 33			
Tr. Full Moon, *Apr.*	6 8 25 11			

Hence it appears, that the mean time of Full Moon in *April*, *A.D.* 30 Old Stile, was on the 6th day, at 25 min. 11 ſec. paſt VIII in the evening.

To calculate the true time of New or Full Moon in any given year and month before the Christian Æra.

PRECEPT I. Find a year in the 18th century, which being added to the given number of years before Chriſt diminiſhed by one, ſhall make a number of complete centuries.

II. Find this number of centuries in Table VI. and ſubtract the Time and Anomalies belonging to it from thoſe of the mean New Moon in *March*, the above-found year of the 18th century; and the remainder will denote the Time and Anomalies, &c. of the mean New Moon in *March*, the given year before Chriſt.—Then, for the true time of that New Moon, in any month of that year, proceed in the manner taught above.

EXAMPLE IV.

Required the mean time of New Moon in May, *Old Stile, the year before Chriſt* 585?

The years 584 added to 1716, make 2300, or 23 centuries.

By the Precepts.	New Moon.	Sun's Anom.	Moon's Anom.	Sun fro. Node.
	D. H. M. S.	s ° ′ ″	s ° ′ ″	s ° ′ ″
March 1716,	11 17 33 29	8 22 50 39	4 4 14 2	4 27 17 5
2300 years ſubt.	11 5 57 53	11 19 47 0	1 5 59 0	7 25 27 0
Mar. bef. Chr. 585,	0 11 35 36	9 3 3 39	2 28 15 2	9 1 50 5
Add 3 Lunations,	88 14 12 9	2 27 18 58	2 17 27 1	3 2 0 42
May bef. Chr. 585,	28 1 47 45	0 0 22 37	5 15 42 3	0 3 50 47
Firſt Equation,	— 1 37	5 15 41 27	— 36	Sun fro. Node, and Arg. 4th equation.
Time once equat.	28 1 46 8	6 14 41 10	5 15 41 27	
Second Equation,	+ 2 14 58	Arg. 3d equat.	Arg. 2d equat.	
Time twice equat.	28 4 1 6			
Third Equation,	+ 1 13			
Time thrice equat.	28 4 2 19			
Fourth Equation,	+ 12			
True New Moon,	28 4 2 31			

So the mean time was *May* 28th, at 2 minutes 31 ſeconds paſt IV in the afternoon.

These Tables are calculated for the meridian of *London*; but they will ferve for any other place, by fubtracting four minutes from the tabular time, for every degree that the meridian of the given place is weftward of *London*, or adding four minutes for every degree that the meridian of the given place is eaftward: as in

EXAMPLE V.

Required the true mean time of Full Moon at Alexandria *in* Ægypt, *long.* 30°, 21′, 45″ E. *in* September, *Old Stile, the year before Chrift* 201?

The years 200 added to 1800, make 2000, or 20 centuries.

By the Precepts.	New Moon.				Sun's Anom.				Moon's Anom				Sun fro. Node.			
	D.	H.	M.	S.	s	°	′	″	s	°	′	″	s	°	′	″
March 1800,	13	0	22	17	8	23	19	55	10	7	52	36	11	3	58	24
Add 1 Lunation,	29	12	44	3	0	29	6	19	0	25	49	0	1	0	40	14
From the Sum,	42	13	6	20	9	22	26	14	11	3	41	36	0	4	38	38
Subtr. 2000 years,	27	18	9	19	0	8	50	0	0	15	42	0	6	27	45	0
N.M. bef Chr. 201.	14	18	57	1	9	13	36	14	10	17	59	36	5	6	53	38
Add { 6 Lunations,	177	4	24	18	5	24	37	56	5	4	54	3	6	4	1	24
Add { half Lunat.	14	18	22	2	0	14	33	10	6	12	54	30	0	15	20	7
Full Moon, *Sept.*	22	17	43	21	3	22	47	20	10	5	48	9	11	26	15	9
Firft Equation,	—	3	53	9	10	4	19	52	—	1	28	17	Sun fro. Node, and Arg. 4th equation.			
Time once equat.	22	13	50	12	5	18	27	28	10	4	19	52				
Second Equation,	—	8	25	4	Arg. 3d equat.				Arg. 2d equat.							
Time twice equat.	22	5	25	8												
Third Equation,			—	58												
Time thrice equat.	22	5	24	10												
Fourth Equation,			—	12												
Tr. time at *London*,	22	5	23	58												
Add for *Alexandria*,		2	1	27												
True time there,	22	7	25	25												

Thus it appears, that the true mean time of Full Moon at *Alexandria*, in *September*, Old Stile, the year before Chrift 201, was the 22d day, at 25 min. 25 fec. after VII in the evening.

EXAMPLE

EXAMPLE VI.

Required the true mean time of Full Moon at Babylon, *long.* 36°, 25′, 15″ E. *in* October, *Old Stile, the* 4008*th year before the first year of Christ, or* 4007 *before the year of his birth?*

The years 4007 added to 1793, make 5800, or 58 centuries.

By the Precepts.	New Moon.				Sun's Anom.				Moon's Anom.				Sun fro. Node.			
	D.	H.	M.	S.	s	°	′	″	s	°	′	″	s	°	′	″
March 1793,	30	9	13	55	9	10	16	11	8	7	37	58	7	6	18	26
Subtr. 5800 years,	15	12	38	7	10	21	35	0	6	24	43	0	9	13	1	0
N.M.bef.Chr.4007	14	20	35	48	10	18	41	11	1	12	54	58	9	23	17	26
Add { 7 Lunations,	206	17	8	21	6	23	44	15	6	0	43	3	7	4	41	38
Add { half Lunat.	14	18	22	2	0	14	33	10	6	12	54	30	0	15	20	7
Full Moon, *October*,	22	8	6	11	5	26	58	36	1	26	32	31	5	13	19	11
First Equation,		—	13	28	1	26	27	26		—	5	5	Sun fro. Node,			
Time once equat.	22	7	52	43	4	0	31	10	1	26	27	26	and Arg. 4th			
Second Equation,	+	8	29	20	Arg. 3d equat				Arg 2d equat.				equation.			
Time twice equat.	22	16	22	3												
Third Equation,		—	4	10												
Time thrice equat.	22	16	17	53												
Fourth Equation,			—	51												
Full Moon at *London*	22	16	17	2												
Add for *Babylon*,		2	25	41												
True time there,	22	18	42	43												

So that, on the meridian of *London*, the true time was *October* 23d, at 17 min. 2 sec. past IV in the morning; but at *Babylon*, the true time was *October* 23d, at 42 min. 43 sec. past VI in the morning.—This is supposed by some to have been the year of the Creation.

To calculate the true time of New or Full Moon in any given year and month after the 18*th century.*

Precept I. Find a year of the same number in the 18th century with that of the year proposed, and take out the mean Time and Anomalies, &c. of New Moon in *March*, Old Stile, for that year, in Table I.

II. Take so many years from Table VI. as when added to the above-mentioned year in the 18th century, will answer to the given year in which the New or Full Moon is required; and take out the first New Moon, with its Anomalies, for these complete centuries.

III. Add

III. Add all theſe together, and then work in all reſpects as ſhewn above, only remember to ſubtract a Lunation and its Anomalies, when the above-mentioned addition carries the New Moon beyond the 31ſt of *March*; as in the following example:

EXAMPLE VII.

Required the true mean time of New Moon in July, *Old Stile,* A. D. 2180?

Four centuries (or 400 years) added to *A. D.* 1780, makes 2180.

By the Precepts.	New Moon. D. H. M. S.	Sun's Anom. s ° ' "	Moon's Anom. s ° ' "	Sun fro. Node. s ° ' "
March 1780,	23 23 1 44	9 4 18 13	1 21 7 47	10 18 21 1
Add 400 years,	17 8 43 29	0 13 24 0	10 1 28 0	6 17 49 0
From the ſum	41 7 45 13	9 17 42 13	11 22 35 47	5 6 10 1
Subtr. 1 Lunation,	29 12 44 3	0 29 6 19	0 25 49 0	1 0 40 14
New ☽ *March* 2180,	11 19 1 10	8 18 35 54	10 26 46 47	4 5 29 47
Add 4 Lunations,	118 2 56 12	3 26 25 17	3 13 16 2	4 2 40 56
New ☽ *July* 2180,	7 21 57 22	0 15 1 11	2 10 2 49	8 8 10 43
Firſt Equation,	— 1 3 41	3 9 38 38	— 24 11	Sun fro. Node, and Arg. 4th equation.
Time once equated,	7 20 53 41	10 5 22 33	2 9 38 38	
Second Equation,	+ 9 24 8	Arg. 3d equat.	Arg. 2d equat.	
Time twice equat.	8 6 17 49			
Third Equation.	+ 3 56			
Time thrice equat.	8 6 21 45			
Fourth Equation,	+ 1 8			
True time, *July*,	8 6 22 53			

True mean time, *July* 8, at 22 minutes 53 ſeconds paſt VI in the evening.

In keeping by the Old Stile, we are always ſure to be right, by adding or ſubtracting whole hundreds of years to or from any given year in the 18th century. But in the New Stile we may be very apt to make miſtakes, on account of the Leap-year's not coming in regularly every fourth year: And therefore, when we go without the limits

limits of the 18th century, we had beſt keep to the Old Stile, and at the end of the calculation reduce the time to the New. Thus, in the 22d century, there will be 14 days difference between the Stiles; and therefore, the true time of New Moon in this laſt Example being reduced to the New Stile, will be the 22d of *July*, at 22 minutes 53 ſeconds paſt VI in the evening.

To calculate the true place of the Sun for any given moment of time.

Precept I. In Table XII. find the next leſſer year in number to that in which the Sun's place is ſought, and write out his mean Longitude and Anomaly anſwering thereto: to which add his mean Motion and Anomaly for the complete reſidue of years, months, days, hours, minutes, and ſeconds down to the given time, and this will be the Sun's mean Place and Anomaly at that time, in the Old Stile, provided the ſaid time be in any year after the Chriſtian æra. *See the firſt following Example.*

II. Enter Table XIII. with the Sun's mean Anomaly, and making proportions for the odd minutes and ſeconds thereof, take out the Equation of the Sun's center: which, being applied to his mean Place, as the title *Add* or *Subtract* directs, will give his true place or Longitude from the Vernal Equinox, at the time for which it was required.

III. To calculate the Sun's place for any time in a given year before the Chriſtian æra, take out his mean Longitude and Anomaly for the firſt year thereof, and from theſe numbers ſubtract the mean Motions and Anomalies for the complete hundreds or thouſands next above the given year; and, to the remainders, add thoſe for the reſidue of years, months, &c. and then work in all reſpects as above. *See the ſecond Example following.*

EXAMPLE I.

Required the Sun's true place, March 20*th*, *Old Stile*, 1764, *at* 22 *hours* 30 *minutes* 25 *seconds paſt noon?*— *In common reckoning*, March 21*ſt*, *at* 10 *hours* 30 *minutes* 25 *seconds in the forenoon.*

		Sun's Longitude.				Sun's Anomaly.			
		s	°	′	″	s	°	′	″
To the radical year after Chriſt — —	1701	9	20	43	50	6	13	1	0
Add complete years — — —	{ 60	0	0	27	12	11	29	26	0
	{ 3	11	29	17	0	11	29	14	0
	March	1	28	9	11	1	28	9	0
Biſſextile, Days —	20		20	41	55		20	41	55
Hours —	22			54	13			54	13
Minutes —	30			1	14			1	14
Seconds —	25				1				1
Sun's mean place at the given time — —		0	10	14	36	9	1	27	23
Equation of the Sun's center, add — —			1	55	31	Mean Anomaly.			
Sun's true place at the ſame time — —		0 . 12 . 10 . 7 or ♈ 12 10 7							

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EXAMPLE II.

Required the Sun's true place, October 23*d Old Stile, at* 16 *hours* 57 *minutes past noon, in the* 4008*th year before the year of Christ* 1; *which was the* 4007*th before the year of his birth, and the year of the* Julian *period* 706?

By the Precepts.

		Sun's Longitude.				Sun's Anomaly.			
		s	°	'	"	s	°	'	"
From the radical numbers after Christ — —	1	9	7	53	10	6	28	48	0
Subtract those for 5000 complete years — —		1	7	46	40	10	13	25	0
Remains, for a new radix		8	0	6	30	8	15	23	0
To which add, to bring it to the given time: complete years — —	900	0	6	48	0	11	21	37	0
	80	0	0	36	16	11	29	15	0
	12	0	0	5	26	11	29	53	0
	October	8	29	4	54	8	29	4	0
	Days 23		22	40	12		22	40	12
	Hours 16			39	26			39	26
	Minutes 57			2	20			2	20
Sun's mean place at the given time — —		6	0	3	4	5	28	33	58
Equation of the Sun's center subtract — —				3	4	Sun's Anomaly.			
Sun's true place at the same time — —		6	0	0	0 or	♎	0	0	0

So that in the meridian of *London*, the Sun was then juſt entering the ſign ♎ *Libra*, and conſequently was upon the point of the Autumnal Equinox.

If to the above time of the Autumnal Equinox at *London*, we add 2 hours 25 minutes 4 ſeconds for the Longitude of *Babylon*, we ſhall have for the time of the ſame Equinox, at that place, *October* 23d, at 19 hours 22 minutes 41 ſeconds; which in the common way of reckoning, is *October* 24th, at 22 minutes 41 ſeconds paſt VII in the morning*.

And it appears by Example VI. that in the ſame year, the true time of Full Moon at *Babylon* was *October* 23d, at 42 minutes 46 ſeconds after VI in the morning; ſo that the Autumnal Equinox was on the day next after the day of Full Moon.—The Dominical letter for that year was *G*, and conſequently the 24th of *October* was on a *Wedneſday*.

* The reaſon why this calculation makes the Autumnal Equinox, in the year of the *Julian Period* 706, to be two days ſooner than the time of the ſame Equinox mentioned in page 153, is, that in *that* page only the mean time is taken into the account, as if there was no Equation of the Sun's motion. The Equation at the Autumnal Equinox then, did not exceed an hour and a quarter, when reduced to time.—But, in the year of Chriſt 1756, (which was 5763 years after) the Equation at the Autumnal Equinox amounted to 1 day 22 hours 24 minutes, by which quantity the true time fell later than the mean.—So that, if we conſider the *true* time of this laſt-mentioned Equinox, only as *mean* time, the mean Motion of the Sun carried thence back to the Autumnal Equinox in the year of the *Julian Period* 706, will fix it to the 25th of *October* in that year.

To find the Sun's diſtance from the Moon's aſcending Node, at the time of any given New or Full Moon; and conſequently, to know whether there is an Eclipſe at that time, or not.

The Sun's diſtance from the Moon's aſcending Node is the argument for finding the Moon's fourth Equation in the Syzygies, and therefore it is taken into all the foregoing Examples in finding the times of theſe Phenomena.—Thus, at the time of mean New Moon in *April* 1764, the Sun's mean Diſtance from the aſcending Node, is $0^s\ 5^\circ\ 35'\ 2''$. *See Example* I. p. 320.

The deſcending Node is oppoſite to the aſcending one, and they are juſt ſix Signs diſtant from each other.

When the Sun is within 17 degrees of either of the Nodes at the time of New Moon, he will be eclipſed at that time: and when he is within 12 degrees of either of the Nodes at the time of Full Moon, the Moon will be then eclipſed.—Thus we find that there will be an Eclipſe of the Sun at the time of New Moon in *April*, 1764.

But the true time of that New Moon comes out by the Equations to be 50 minutes 46 ſeconds later than the mean time thereof, by comparing theſe times in the above Example: and therefore, we muſt add the Sun's motion from the Node during that interval to the above mean Diſtance $0^s\ 5^\circ\ 35'\ 2''$, which motion is found in Table XII. for 50 minutes 46 ſeconds, to be $2'\ 12''$. And to this we muſt apply the Equation of the Sun's mean Diſtance from the Node, in Table XV. found by the Sun's Anomaly, which, at the mean time of New Moon in Example I. is $9^s\ 1^\circ\ 26'\ 19''$; and then we ſhall have the Sun's true Diſtance from the Node, at the true time of New Moon, as follows:

At

	Sun from Node. s	°	'	"
At the mean time of New Moon in *April* 1764 — —	0	5	35	2
Sun's motion from the Node for — { 50 minutes			2	10
{ 46 seconds				2
Sun's mean distance from Node at true New Moon — —	0	5	37	14
Equation of mean distance from Node, add — —		2	5	0
Sun's true distance from the ascending Node — —	0	7	42	14

which, being far within the above limit of 17 degrees, shews that the Sun must then be eclipsed.

And now we shall shew how to project this, or any other eclipse, either of the Sun or Moon.

To project an Eclipse of the Sun.

In order to this, we must find the ten following Elements, by means of the Tables.

1. The true time of conjunction of the Sun and Moon; and at that time, 2. The semidiameter of the Earth's disc, as seen from the Moon, which is equal to the Moon's horizontal parallax. 3. The Sun's distance from the solstitial Colure to which he is then nearest. 4. The Sun's declination. 5. The angle of the Moon's visible path with the Ecliptic. 6. The Moon's latitude. 7. The Moon's true horary motion from the Sun. 8. The Sun's semidiameter, 9. The Moon's. 10. The semidiameter of the Penumbra.

We shall now proceed to find these Elements for the Sun's Eclipse in *April* 1764.

To find the true time of New Moon. This, by Example I. p. 320, is found to be on the first day of the said month, at 30 minutes 25 seconds after X in the morning.

2. *To*

2. *To find the Moon's horizontal parallax, or semidiameter of the Earth's disc, as seen from the Moon.* Enter Table XVII. with the signs and degrees of the Moon's Anomaly (making proportions, because the Anomaly is in the Table only to every 6th degree), and thereby take out the Moon's horizontal parallax; which, for the above time, answering to the Anomaly $11^s\ 9^\circ\ 24'\ 21''$, is $54'\ 43''$.

4. *To find the Sun's distance from the nearest Solstice, viz. the beginning of Cancer, which is 3^s or 90° from the beginning of Aries.* It appears by the Example on page 328 (where the Sun's place is calculated to the above time of New Moon), that the Sun's longitude from the beginning of Aries is then $0^s\ 12^\circ\ 10'\ 7''$, that is, the Sun's place at that time is ♈ Aries, $12^\circ\ 10'\ 7''$.

	s	°	′	″
Therefore from — — —	3	0	0	0
Subtract the Sun's longitude or place	0	12	10	7
Remains the Sun's distance from the Solstice ♋ — } =	2	17	49	53

Or $77^\circ\ 49'\ 53''$; each sign containing 30 degrees.

4. *To find the Sun's declination.* Enter Table XIV. with the Signs and degrees of the Sun's true place, viz. $0^s\ 12^\circ$, and making proportion for the $10'\ 7''$, take out the Sun's declination answering to his true place, and it will be found to be $4^\circ\ 49'$ North.

5. *To find the Moon's latitude.* This depends on her distance from her ascending Node, which is the same as the Sun's distance from it at the time of New Moon; and with this the Moon's Latitude is found in Table XVI.

Now we have already found, that the Sun's equated distance from the ascending Node, at the time of New Moon in *April* 1764, is $0^s\ 7^\circ\ 42'\ 14''$. *See the preceding page.*

Therefore, enter Table XVI. with 0 signs at the top, and 7 and 8 degrees at the left hand, and take out $36'$ and $39''$, the latitude for 7°; and

41′

41′ 51″, the latitude for 8°: and by making proportion between these latitudes for the 42′ 14″ by which the Moon's distance from the Node exceeds 7 degrees; her true latitude will be found to be 40′ 18″ north ascending.

6. *To find the Moon's true horary motion from the Sun.* With the Moon's Anomaly, viz. 11ˢ 9° 24′ 21″, enter Table XVII. and take out the Moon's horary motion; which, by making proportion in that Table, will be found to be 30′ 22″. Then, with the Sun's Anomaly, 9ˢ 1° 26′ 19″, take out his horary motion 2′ 28″ from the same Table: and subtracting the latter from the former, there will remain 27′ 54″ for the Moon's true horary motion from the Sun.

7. *To find the angle of the Moon's visible path with the Ecliptic.* This, in the projection of Eclipses, may be always rated at 5° 35′, without any sensible error.

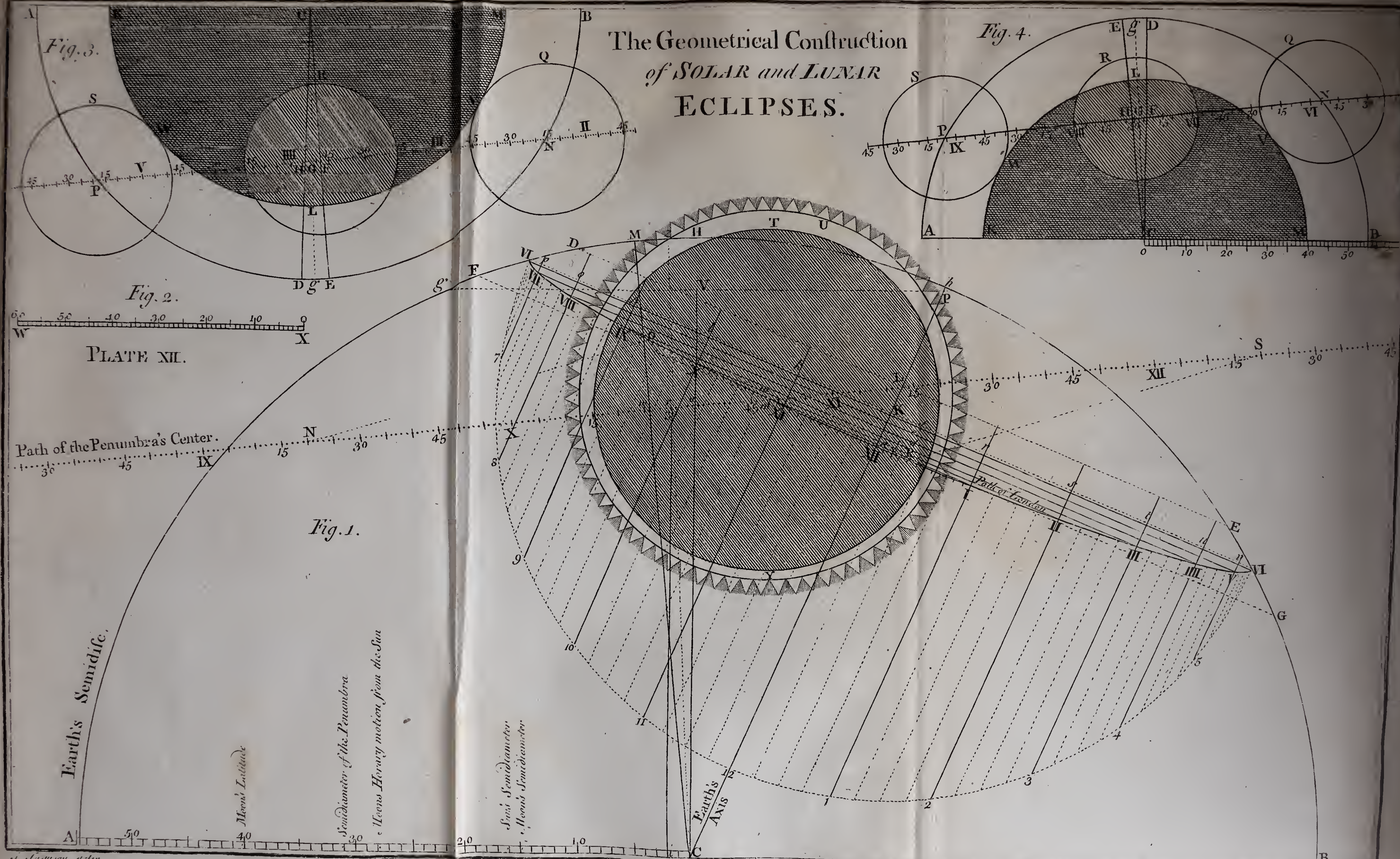
8, 9. *To find the semidiameters of the Sun and Moon.* These are found in the same Table, and by the same Arguments, as their horary Motions.—In the present case the Sun's Anomaly gives his semidiameter 16′ 6″, and the Moon's Anomaly gives her semidiameter 14′ 57″.

10. *To find the semidiameter of the Penumbra.* Add the Moon's semidiameter to the Sun's, and their sum will be the semidiameter of the Penumbra, viz. 31′ 3″.

Now collect these Elements, that they may be found the more readily when they are wanted in the construction of this Eclipse.

1. True time of New Moon in *April* 1764	1	10	30	25
		°	′	″
2. Semidiameter of the Earth's disc		0	54	43
3. Sun's dist. from the nearest Solst.		77	49	53
4. Sun's declination, North		4	49	0
5. Moon's latitude, North ascending		0	40	18

6. Moon's



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6. Moon's horary motion from the Sun	0	27	54
7. Angle of the Moon's visible path with the Ecliptic	5	35	0
8. Sun's semidiameter		16	6
9. Moon's semidiameter		14	57
10. Semidiameter of the Penumbra		31	3

To project an Eclipse of the Sun geometrically.

Make a scale of any convenient length, as *AC*, and divide it into as many equal parts as the Earth's semi-disc contains minutes of a degree, which, at the time of the Eclipse in *April* 1764, is 54′ 43″. Then, with the whole length of the scale as a radius, describe the semicircle *AMB* upon the center *C*; which semicircle shall represent the northern half of the Earth's enlightened disc, as seen from the Sun. PLATE XII. Fig. I.

Upon the center *C* raise the straight line *CH*, perpendicular to the diameter *ACB*; so *ACB* shall be a part of the Ecliptic, and *CH* its Axis.

Being provided with a good sector, open it to the radius *CA* in the line of chords; and taking from thence the chord of 23½ degrees in your compasses, set it off both ways from *H*, to *g* and to *h*, in the periphery of the semi-disc; and draw the straight line *gVh*, in which the North Pole of the Disc will be always found.

When the Sun is in Aries, Taurus, Gemini, Cancer, Leo, and Virgo, the North Pole of the Earth is enlightened by the Sun: but while the Sun is in the other six Signs, the south Pole is enlightened, and the North Pole is in the dark.

And when the Sun is in Capricorn, Aquarius, Pisces, Aries, Taurus, and Gemini, the northern half of the Earth's Axis *C* XII *P* lies to the right hand of the Axis of the Ecliptic, as seen from the Sun; and to the left hand, while the Sun is in the other six Signs.

Open

Open the sector till the radius (or distance of the two 90's) of the Signs be equal to the length of *Vb*, and take the sine of the Sun's distance from the Solstice (77° 49′ 53″) as nearly as you can guess, in your compasses, from the line of sines, and set off that distance from *V* to *P* in the line *gVb*, because the Earth's Axis lies to the right hand of the Axis of the Ecliptic in this case, the Sun being in Aries; and draw the straight line *C* XII *P* for the Earth's Axis, of which *P* is the North Pole. If the Earth's Axis had lain to the left hand from the Axis of the Ecliptic, the distance *VP* would have been set off from *V* toward *g*.

To draw the parallel of Latitude of any given place, as suppose *London*, or the path of that place on the Earth's enlightened Disc as seen from the Sun, from Sun-rise till Sun-set, take the following method:

Subtract the Latitude of *London*, 51½° from 90°, and the remainder 38½° will be the co-latitude, which take in your compasses from the line of chords, making *C A* or *C B* the radius, and set it from *b* (where the Earth's Axis meets the Periphery of the Disc) to VI and VI, and draw the occult or dotted line VI *K* VI. Then, from the points where this line meets the Earth's Disc, set off the chord of the Sun's declination 4° 49′ to *D* and *F*, and to *E* and *G*, and connect these points by the two occult lines *F* XII *G* and *D L E*.

Bisect *L K* XII in *K*, and through the point *K* draw the black line VI *K* VI. Then making *CB* the radius of a line of sines on the sector, take the co latitude of *London* 38½° from the sines in your compasses, and set it both ways from *K*, to VI and VI.—These hours will be just in the edge of the disc at the Equinoxes, but at no other time in the whole year.

With the extent *K* VI, taken into your compasses, set one foot in *K* (in the black line below the occult one) as a center, and with the other foot describe

describe the ſemicircle VI 7 8 9 10, &c. and divide it into 12 equal parts. Then from theſe points of diviſion, draw the occult lines 7 *p*, 8 *o*, 9 *n*, &c. parallel to the Earth's Axis *C* XII *P*.

With the ſmall extent *K* XII as a radius, deſcribe the quadrantal Arc XII *f*, and divide it into ſix equal parts, as XII *a*, *a b*, *b c*, *c d*, *d e*, and *e f*; and through the diviſion-points, *a*, *b*, *c*, *d*, *e*, draw the occult lines VII *e* V, VIII *d* IV, IX *c* III, X *b* II, and XI *a* I, all parallel to VI *K* VI, and meeting the former occult lines 7 *p*, 8 *o*, &c. in the points VII VIII IX X XI, V IV III II and I: which points ſhall mark the ſeveral ſituations of *London* on the Earth's Diſc, at theſe hours reſpectively as ſeen from the Sun; and the elliptic Curve VI VII VIII, &c. being drawn through theſe points, ſhall repreſent the parallel of latitude, or path of *London* on the Diſc, as ſeen from the Sun, from its riſing to its ſetting.

N. B. If the Sun's declination had been ſouth, the diurnal path of *London* would have been on the upper ſide of the line VI *K* VI, and would have touched the line *D L E* in *L*.—It is requiſite to divide the horary ſpaces into quarters, (as ſome are in the figure,) and, if poſſible, into minutes alſo.

Make *C B* the radius of a line of chords on the ſector, and taking therefrom the chord of 5° 35′, the angle of the Moon's viſible path with the Ecliptic, ſet it off from *H* to *M* on the left hand of *C H*, the Axis of the Ecliptic, becauſe the Moon's latitude is north aſcending. Then draw *C M* for the Axis of the Moon's Orbit, and biſect the angle *M C H* by the right line *C z*.—If the Moon's latitude had been north deſcending, the Axis of her Orbit would have been on the right hand from the Axis of the Ecliptic.—*N. B.* The Axis of the Moon's Orbit lies the ſame way when her latitude is ſouth aſcending, as when it is north aſcending; and the ſame way when ſouth deſcending, as when north deſcending.

Take the Moon's latitude 40′ 18″ from the ſcale *C A* in your compaſſes, and ſet it from *i* to *x* in the biſecting line *C z*, making *i x* parallel to *C y z* and through *x*, at right-angles to the Axis of the Moon's Orbit *C M*, draw the ſtraight line *N w x y S* for the path of the Penumbra's center over the Earth's Diſc.—The point *w*, in the Axis of the Moon's Orbit, is that where the Penumbra's center approaches neareſt to the center of the Earth's Diſc, and conſequently is the middle of the general Eclipſe: the point *x* is that where the conjunction of the Sun and Moon falls, according to equal time by the Tables; and the point *y* is the ecliptical conjunction of the Sun and Moon.

Take the Moon's true horary motion from the Sun, 27′ 54″, in your compaſſes, from the ſcale *C A* (every diviſion of which is a minute of a degree), and with that extent make marks along the path of the Penumbra's center; and divide each ſpace from mark to mark, into ſixty equal parts or horary minutes, by dots; and ſet the hours to every 60th minute in ſuch a manner, that the dot ſignifying the inſtant of New Moon by the Tables, may fall into the point *x*, half way between the Axis of the Moon's Orbit, and the Axis of the Ecliptic; and then, the reſt of the dots will ſhew the points of the Earth's Diſc, where the Penumbra's center is at the inſtants denoted by them, in its tranſit over the Earth.

Apply one ſide of a ſquare to the line of the Penumbra's path, and move the ſquare backward and forward, until the other ſide of it cuts the ſame hour and minute (as at *m* and *n*) both in the path of *London*, and in the path of the Penumbra's center: and the particular minute or inſtant which the ſquare cuts at the ſame time in both paths, ſhall be the inſtant of the viſible conjunction of the Sun and Moon, or greateſt obſcuration of the Sun, at the place for which the conſtruction is made, namely *London*, in the preſent example; and this inſtant is at 47½ minutes paſt X o'clock in the morning; which is 17 minutes 5 ſeconds later than the tabular time of true conjunction.

Take the Sun's ſemidiameter, 16′ 6″, in your compaſſes, from the ſcale *CA*, and ſetting one foot in the path of *London* at *m*, namely at 47½ minutes paſt X, with the other foot deſcribe the circle *UY*, which ſhall repreſent the Sun's Diſc as ſeen from *London* at the greateſt obſcuration.—Then take the Moon's ſemidiameter, 14′ 57″, in your compaſſes from the ſame ſcale; and ſetting one foot in the path of the Penumbra's center at *m*, 47½ minutes after X, with the other foot deſcribe the circle *TY* for the Moon's Diſc, as ſeen from *London*, at the time when the Eclipſe is at the greateſt; and the portion of the Sun's Diſc which is hid or cut off by the Moon's, will ſhew the quantity of the Eclipſe at that time; which quantity may be meaſured on a line equal to the Sun's diameter, and divided into twelve equal parts or digits.

Laſtly, take the ſemidiameter of the Penumbra 31′ 3″, from the ſcale *CA* in your compaſſes; and ſetting one foot in the line of the Penumbra's central path, on the left hand from the Axis of the Ecliptic, direct the other foot toward the path of *London*; and carry that extent backward and forward till both the points of the compaſſes fall into the ſame inſtant in both the paths: and that inſtant will denote the time when the Eclipſe begins at *London*.—Then, do the like on the right hand of the Axis of the Ecliptic; and where the points of the compaſſes fall into the ſame inſtant in both the paths, that inſtant will be the time when the Eclipſe ends at *London*.

Theſe trials give 20 minutes after IX in the morning for the beginning of the Eclipſe at *London*, at the points *N* and *O*; 47½ minutes after X, at the points *m* and *n*, for the time of greateſt obſcuration; and 18 minutes after XII, at *R* and *S*,

 for

for the time when the Eclipse ends; according to mean or equal time.

From these times we must subtract the equation of natural days, viz. 3 minutes 48 seconds, in Leap year *April* 1, and we shall have the apparent times; namely IX hours 16 minutes 12 seconds for the beginning of the Eclipse, X hours 43 minutes 42 seconds for the time of greatest obscuration, and XII hours 14 minutes 12 seconds for the time when the Eclipse ends.—But the best way is to apply this equation to the true equal time of New Moon, before the projection be begun; as is done in Example I. For the motion or position of places on the Earth's Disc answer to apparent or solar time.

In this construction it is supposed, that the angle under which the Moon's Disc is seen, during the whole time of the Eclipse, continues invariably the same; and that the Moon's motion is uniform and rectilinear during that time.—But these suppositions do not exactly agree with the truth; and therefore, supposing the Elements given by the Tables to be accurate, yet the times and phases of the Eclipse, deduced from its construction, will not answer exactly to what passeth in the Heavens; but may be at least two or three minutes wrong, though done with the greatest care.—Moreover, the paths of all places of considerable latitudes are nearer the center of the Earth's Disc, as seen from the Sun, than those constructions make them; because the Disc is projected as if the Earth were a perfect sphere, although it is known to be a spheroid. Consequently the Moon's shadow will go farther northward in all places of northern latitude, and farther southward in all places of southern latitude, than it is shewn to do in these projections.—According to *Mayer*'s Tables, this Eclipse will be about a quarter of an hour sooner than either these Tables,

 or

or Mr. *Flamstead*'s, or Dr. *Halley*'s make it: and *Mayer*'s Tables do not make it annular at *London*.

The projection of Lunar Eclipses.

When the Moon is within 12 degrees of either of her Nodes, at the time when she is Full, she will be eclipsed, otherwise not.

We find by Example II, page 321, that at the time of mean Full Moon in *May* 1762, the Sun's distance from the ascending Node was only 4° 49′ 35″; and the Moon being then opposite to the Sun, must have been just as near her descending Node, and was therefore eclipsed.

The elements for constructing an Eclipse of the Moon are eight in number, as follow:

1. The true time of Full Moon: and at that time, 2. The Moon's horizontal parallax. 3. The Sun's semidiameter. 4. The Moon's. 5. The semidiameter of the Earth's shadow at the Moon. 6. The Moon's latitude. 7. The angle of the Moon's visible path with the Ecliptic. 8. The Moon's true horary motion from the Sun.——— Therefore,

1. *To find the true time of Full Moon.* Work as already taught in the Precepts.—Thus we have the true time of Full Moon in *May* 1762 (see Example II. page 321), on the 8th day, at 50 minutes 50 seconds past III o'clock in the morning.

2. *To find the Moon's horizontal Parallax.* Enter Table XVII. with the Moon's mean Anomaly (at the above Full) 9ˢ 2° 42′ 42″, and thereby take out her horizontal Parallax; which, by making the requisite proportion, will be found to be 57′ 20″.

3, 4. *To find the semidiameters of the Sun and Moon.* Enter Table XVII. with their respective Anomalies, the Sun's being 10ˢ 7° 27′ 45″ (by the above Example) and the Moon's 9ˢ 2° 42′ 42″; and thereby take out their respective semidiameters: the Sun's 15′ 56″, and the Moon's 15′ 39″.

5. *To find the ſemidiameter of the Earth's ſhadow at the Moon.* Add the Sun's horizontal parallax, which is always 10″, to the Moon's, which in the preſent caſe is 57′ 20″, the ſum will be 57′ 30″, from which ſubtract the Sun's ſemidiameter 15′ 56″, and there will remain 41′ 34″ for the ſemidiameter of that part of the Earth's ſhadow which the Moon then paſſes through.

6. *To find the Moon's Latitude.* Find the Sun's true diſtance from the aſcending Node (as already taught in page 331) at the true time of Full Moon; and this diſtance, increaſed by ſix ſigns, will be the Moon's true diſtance from the ſame Node; and conſequently the argument for finding her true latitude, as ſhewn in page 333.

Thus, in Example II. the Sun's mean diſtance from the aſcending Node was 0ˢ 4° 49′ 35″, at the time of mean Full Moon: but it appears by the Example, that the true time thereof was 6 hours 33 minutes 38 ſeconds ſooner than the mean time, and therefore we muſt ſubtract the Sun's motion from the Node (found in Table XII. page 312) during this interval, from the above mean diſtance, 0ˢ 4° 49′ 35″, in order to have his mean diſtance from it at the true time of Full Moon.—Then to this apply the Equation of his mean diſtance from the Node found in Table XV. by his mean Anomaly 10ˢ 7° 27′ 45″; and laſtly, add ſix ſigns: ſo ſhall the Moon's true diſtance from the aſcending Node be found as follows:

		s	°	′	″
Sun from Node at mean Full Moon		0	4	49	35
His motion from it in	6 hours			15	35
	33 minutes			1	26
	38 ſeconds				2
Sum, ſubtract from the uppermoſt line				17	3
Remains his mean diſtance at true Full Moon – –		0	4	32	32

Equation

	s	°	′	″
Equation of his mean distance, add		1	38	0
Sun's true distance from the Node	0	6	10	32
To which add	6	0	0	0
And the sum will be	6	6	10	32

Which is the Moon's true distance from her ascending Node at the true time of her being Full; and consequently the argument for finding her true Latitude at that time.—Therefore, with this argument enter Table XVI. making proportion between the latitudes belonging to the 6th and 7th degree of the argument at the left hand (the signs being at the top) for the 10′ 32″, and it will give 32′ 21″ for the Moon's true latitude, which appears by the Table to be south descending.

7. *To find the angle of the Moon's visible path with the Ecliptic.* This may be stated at 5° 35′, without any error of consequence in the projection of the Eclipse.

8. *To find the Moon's true horary motion from the Sun.* With their respective Anomalies take out their horary motions from Table XVII. in page 316; and the Sun's horary motion subtracted from the Moon's, leaves remaining the Moon's true horary motion from the Sun: in the present case 30′ 52″.

Now collect these Elements together for use.

	D.	H.	M.	S.
1. True Time of Full Moon in *May* 1762	8	3	50	50

	°	′	″
2. Moon's horizontal Parallax	0	57	20
3. Sun's semidiameter	0	15	56
4. Moon's semidiameter	0	15	39
5. Semidiameter of the Earth's shadow at the Moon	0	41	34

	°	′	″
6. Moon's true latitude, ſouth deſcending	0	32	21
7. Angle of her viſible path with the Ecliptic	5	35	0
8. Her true horary motion from the Sun	0	30	52

PLATE XII. Theſe Elements being found for the conſtruction of the Moon's Eclipſe in *May* 1762, proceed as follows:

Fig. II. Make a ſcale of any convenient length, as *WX*, and divide it into 60 equal parts, each part ſtanding for a minute of a degree.

Draw the right line *ACB* (Fig. 3.) for part of the Ecliptic, and *CD* perpendicular to it for the ſouthern part of its Axis; the Moon having ſouth latitude.

Add the ſemidiameters of the Moon and Earth's ſhadow together, which, in this Eclipſe, will make 57′ 13″; and take this from the ſcale in your compaſſes, and ſetting one foot in the point *C*, as a center, with the other foot deſcribe the ſemicircle *ADB*; in one point of which the Moon's center will be at the beginning of the Eclipſe, and in another at the end of it.

Take the ſemidiameter of the Earth's ſhadow, 41′ 34″, in your compaſſes from the ſcale, and ſetting one foot in the center *C*, with the other foot deſcribe the ſemicircle *KLM* for the ſouthern half of the Earth's ſhadow, becauſe the Moon's latitude is ſouth in this Eclipſe.

Make *CD* the radius of a line of chords on the ſector, and ſet off the angle of the Moon's viſible path with the Ecliptic, 5° 35′, from *D* to *E*, and draw the right line *CFE* for the ſouthern half of the Axis of the Moon's Orbit, lying to the right hand from the Axis of the Ecliptic *C D*, becauſe the Moon's latitude is ſouth deſcending.— It would have been the ſame way (on the other ſide of the Ecliptic) if her latitude had been north deſcending; but contrary in both caſes, if her

her latitude had been either north aſcending or ſouth aſcending.

Biſect the angle *DCE* by the right line *Cg*, in which line, the true equal time of oppoſition of the Sun and Moon falls, as given by the Tables.

Take the Moon's latitude, 32′ 21″, from the ſcale with your compaſſes, and ſet it from *C* to *G*, in the line *CGg*; and through the point *G*, at right angles to *CFE*, draw the right line *PHGFN* for the path of the Moon's center. Then, *F* ſhall be the point in the Earth's ſhadow, where the Moon's center is at the middle of the Eclipſe; *G*, the point where her center is at the tabular time of her being Full; and *H*, the point where her center is at the inſtant of her ecliptical oppoſition.

Take the Moon's horary motion from the Sun, 30′ 52″, in your compaſſes from the ſcale; and with that extent make marks along the line of the Moon's path *PGN*: then divide each ſpace from mark to mark, into 60 equal parts, or horary minutes, and ſet the hours to the proper dots in ſuch a manner, that the dot ſignifying the inſtant of Full Moon (viz. 50 minutes 50 ſeconds after III in the morning) may be in the point *G*, where the line of the Moon's path cuts the line that biſects the angle *DCE*.

Take the Moon's ſemidiameter, 15′ 39″, in your compaſſes from the ſcale, and with that extent, as a radius, upon the points *N*, *F*, and *P*, as centers, deſcribe the circle *Q* for the Moon at the beginning of the Eclipſe, when ſhe touches the Earth's ſhadow at V; the circle *R* for the Moon at the middle of the Eclipſe; and the circle *S* for the Moon at the end of the Eclipſe, juſt leaving the Earth's ſhadow at *W*.

The point *N* denotes the inſtant when the Eclipſe begins, namely, at 15 minutes 10 ſeconds after II in the morning: the point *F* the middle of the Eclipſe at 47 minutes 45 ſeconds paſt III; and the point *P* the end of the Eclipſe, at 18 minutes after

after V.—At the greateſt obſcuration the Moon is 10 digits eclipſed.

Concerning an antient Eclipſe of the Moon.

It is recorded by *Ptolemy*, from *Hipparchus*, that on the 22d of *September*, the year 201 before the firſt year of Chriſt, the Moon roſe ſo much eclipſed at *Alexandria*, that the eclipſe muſt have begun about half an hour before ſhe roſe.

Mr. *Carey* puts down the Eclipſe in his Chronology as follows, among ſeveral other antient ones, recorded by different authors.

Jul. Per. 4513. *Sept.* 22.	Ecl. o *Per. Calip.* 2 *An.* 54. *Hor.* 7. *P. M. Alexandr. Dig. eccl.* 10. [*Ptolem. l.* 4. *c.* 11.]	*Nabonaſſar* 547 *Meſor.* 16.

That is, in the 4513th year of the *Julian* period, which was the 547th year from *Nabonaſſer*, and the 54th year of the ſecond *Calipic* period, on the 16th day of the month *Meſori* (which anſwers to the 22d of *September*) the Moon was 10 digits eclipſed at *Alexandria*, at 7 o'clock in the evening.

Now, as our Saviour was born (according to the *Dionyſian* or vulgar æra of his birth) in the 4713th year of the *Julian* period, it is plain that the 4513th year of that period was the 200th year before the year of Chriſt's birth; and conſequently 201 years before the year of Chriſt 1.

And, in the year 201, on the 22d of *September*, it appears by Example V. (page 324) that the Moon was full at 26 minutes 28 ſeconds paſt VII in the evening, in the meridian of *Alexandria*.

At that time, the Sun's place was Virgo 26° 14′, according to our Tables; ſo that the Sun was then within 4 degrees of the Autumnal Equinox: and according to calculation he muſt have ſet at *Alexandria* about 5 minutes after VI, and about one degree north of the weſt.

The

The Moon being Full at that time, would have risen just at Sunset, about one degree south of the east, if she had been in either of her Nodes, and her visible place not depressed by Parallax.

But her parallactic depression (as appears from her Anomaly, viz. 10' 6° nearly) must have been 55′ 17″; which exceeded her whole diameter by 24′ 53″; but then, she must have been elevated 33′ 45″ by refraction; which, subtracted from her Parallax, leaves 21′ 32″ for her visible or apparent depression.

And her true latitude was $30\frac{1}{2}'$ north descending, which being contrary to her apparent depression, and greater than the same by 8′ 58″, her true time of rising must have been just about VI o'clock.

Now, as the Moon rose about one degree south of the east at *Alexandria*, where the visible Horizon is land, and not sea, we can hardly imagine her to have been less than 15 or 20 minutes of time above the true Horizon before she was visible.

It appears by Fig. 4, which is a delineation of this Eclipse reduced to the time at *Alexandria*, that the Eclipse began at 53 minutes after V in the evening; and consequently 7 minutes before the Moon was in the true Horizon: to which, if we add 20 minutes for the interval between her true rising and her being visible, we shall have 27 minutes for the time that the Eclipse was begun before the Moon was visibly risen.—The middle of this Eclipse was at 30 minutes past VII, when its quantity was almost 10 digits, and its ending was at 6 minutes past IX in the evening—So that our Tables come as near to the recorded time of this Eclipse as can be expected, after an elapse of 1960 years.

CHAP.

CHAP. XVIII.

Of the fixed Stars.

Why the fixed Stars appear bigger when viewed by the bare eye, than when seen through a telescope.

354. THE Stars are ſaid to be fixed, becauſe they have been generally obſerved to keep at the ſame diſtances from each other, their apparent diurnal revolution being cauſed ſolely by the Earth's turning on its Axis. They appear of a ſenſible magnitude to the bare eye, becauſe the retina is affected not only by the rays of light which are emitted directly from them, but by many thouſands more, which falling upon our eyelids, and upon the aërial particles about us, are reflected into our eyes ſo ſtrongly, as to excite vibrations not only in thoſe points of the retina where the real images of the Stars are formed, but alſo in other points at ſome diſtance round about. This makes us imagine the Stars to be much bigger than they would appear, if we ſaw them only by the few rays which come directly from them, ſo as to enter our eyes without being intermixed with others. Any one may be ſenſible of this, by looking at a Star of the firſt magnitude through a long narrow tube; which, though it takes in as much of the Sky as would hold a thouſand ſuch Stars, it ſcarce renders *that* one viſible.

A proof that they ſhine by their own light.

The more a teleſcope magnifies, the leſs is the aperture through which the Star is ſeen; and conſequently the fewer rays it admits into the eye. Now ſince the Stars appear leſs in a teleſcope which magnifies 200 times than they do to the bare eye, inſomuch that they ſeem to be only indiviſible points, it proves at once that the Stars are at immenſe diſtances from us, and that they ſhine by their own proper light. If they ſhone by borrowed light, they would be as inviſible without teleſcopes as the Satellites of Jupiter are: for theſe

Satellites

Satellites appear bigger when viewed with a good telefcope than the largeft fixed Stars do.

355. The number of Stars difcoverable, in either Hemifphere, by the naked eye, is not above a thoufand. This at firft may appear incredible, becaufe they feem to be without number: But the deception arifes from our looking confufedly upon them, without reducing them into any order. For look but ftedfaftly upon a pretty large portion of the Sky, and count the number of Stars in it, and you will be furprifed to find them fo few. And, if one confiders how feldom the Moon meets with any Stars in her way, although there are as many about her path as in other parts of the Heavens, he will foon be convinced that the Stars are much thinner fown than he was aware of. The *Britifh* catalogue, which, befides the Stars vifible to the bare eye, includes a great number which cannot be feen without the affiftance of a telefcope, contains no more than 3000, in both Hemifpheres.

Their number much lefs than is generally imagined.

350. As we have incomparably more light from the Moon than from all the Stars together, it is the greateft abfurdity to imagine that the Stars were made for no other purpofe than to caft a faint light upon the Earth: efpecially fince many more require the affiftance of a good telefcope to find them out, than are vifible without that inftrument. Our Sun is furrounded by a fyftem of planets and Comets; all which would be invifible from the neareft fixed Star. And from what we already know of the immenfe diftance of the Stars, the neareft may be computed at 32,000,000,000,000 of miles from us, which is further than a cannon-ball would fly in 7,000,000 of years. Hence it is eafy to prove, that the Sun, feen from fuch a diftance, would appear no bigger than a Star of the firft magnitude. From all this it is highly probable that each Star is a Sun to a fyftem of worlds moving round it, though unfeen by us; efpecially as the doctrine of plurality of worlds is rational,

The abfurdity of fuppofing the Stars were made only to fhine upon us in the night.

rational, and greatly manifeſts the Power, Wiſdom, and Goodneſs of the Great Creator.

Their different magnitudes: 357. The Stars, on account of their apparently various magnitudes, have been diſtributed into ſeveral claſſes or orders. Thoſe which appear largeſt, are called *Stars of the firſt magnitude*; *the* next to them in luſtre, *Stars of the ſecond magnitude*; and ſo on to the *ſixth*, which are the ſmalleſt that are viſible to the bare eye. This diſtribution having been made long before the invention of teleſcopes, the Stars which cannot be ſeen without the aſſiſtance of theſe inſtruments, are diſtinguiſhed by the name of *Teleſcopic Stars*.

And diviſion into Conſtellations. 358. The antients divided the ſtarry Sphere into particular Conſtellations, or Syſtems of Stars, according as they lay near one another, ſo as to occupy thoſe ſpaces which the figures of different ſorts of animals or things would take up, if they were there delineated. And thoſe Stars which could not be brought into any particular Conſtellation, were called *unformed Stars*.

The uſe of this diviſion. 359. This diviſion of the Stars into different Conſtellations or Aſteriſms, ſerves to diſtinguiſh them from one another, ſo that any particular Star may be readily found in the Heavens by means of a Celeſtial Globe; on which the Conſtellations are ſo delineated as to put the moſt remarkable Stars into ſuch parts of the figures as are moſt eaſily diſtinguiſhed. The number of the ancient Conſtellations is 48, and upon our preſent Globes about 70. On *Senex*'s Globes, *Bayer*'s Letters are inſerted; the firſt in the Greek Alphabet being put to the biggeſt Star in each Conſtellation, the ſecond to the next, and ſo on; by which means, every Star is as eaſily found as if a name were given to it. Thus, if the Star γ in the Conſtellation of the *Ram* be mentioned, every Aſtronomer knows as well what Star is meant, as if it were pointed out to him in the Heavens.

360. There

360. There is alſo a diviſion of the Heavens into three parts. 1. The *Zodiac* (ζωδιακος) from ζώδιον *Zodion* an Animal, becauſe moſt of the Conſtellations in it, which are twelve in number, are the figures of Animals: as *Aries* the Ram, *Taurus* the Bull, *Gemini* the Twins, *Cancer* the Crab, *Leo* the Lion, *Virgo* the Virgin, *Libra* the Balance, *Scorpio* the Scorpion, *Sagittarius* the Archer, *Capricornus* the Goat, *Aquarius* the Water-bearer, and *Piſces* the Fiſhes. The Zodiac goes quite round the Heavens: it is about 16 degrees broad, ſo that it takes in the Orbits of all the Planets, and likewiſe the Orbit of the Moon. Along the middle of this Zone or Belt is the Ecliptic, or Circle which the Earth deſcribes annually as ſeen from the Sun; and which the Sun appears to deſcribe as ſeen from the Earth. 2. All that Region of the Heavens, which is on the north ſide of the Zodiac, contains 21 Conſtellations. And, 3d, That on the ſouth ſide, 15. The *Zodiac.*

361. The antients divided the *Zodiac* into the above 12 Conſtellations or Signs in the following manner. They took a veſſel with a ſmall hole in the bottom, and having filled it with water, ſuffered the ſame to diſtil drop by drop into another veſſel ſet beneath to receive it; beginning at the moment when ſome Star roſe, and continuing until it roſe the next following night. The water fallen down into the receiver they divided into twelve equal parts: and having two other ſmall veſſels in readineſs, each of them fit to contain one part, they again poured all the water into the upper veſſel, and obſerving the riſing of ſome Star in the *Zodiac*, they at the ſame time ſuffered the water to drop into one of the ſmall veſſels; and as ſoon as it was full they ſhifted it, and ſet an empty one in its place. When each veſſel was full, they took notice what Star of the *Zodiac* roſe; and though this could not be done in one night, yet in many they ob- The manner of dividing it by the antients.

obſerved the riſing of twelve Stars or points, by which they divided the *Zodiac* into twelve parts.

362. The names of the conſtellations, and the number of Stars obſerved in each of them by different Aſtronomers, are as follows:

The ancient Conſtellations.		*Ptolemy.*	*Tycho.*	*Hevel.*	*Flamſt.*
Urſa minor	The Little Bear	8	7	12	24
Urſa major	The Great Bear	35	29	73	87
Draco	The Dragon	31	32	40	80
Cepheus	Cepheus	13	4	51	35
Bootes, *Arctophilax*		23	18	52	54
Corona Borealis	The Northern Crown	8	8	8	21
Hercules, *Engonaſin*	Hercules Kneeling	29	28	45	113
Lyra	The Harp	10	11	17	21
Cygnus, *Gallina*	The Swan	19	18	47	81
Caſſiopea	The Lady in her Chair	13	26	37	55
Perſeus	Perſeus	29	29	46	59
Auriga	The Waggoner	14	9	40	66
Serpentarius, *Ophiuchus*	Serpentarius	29	15	40	74
Serpens	The Serpent	18	13	22	64
Sagitta	The Arrow	5	5	5	18
Aquila, *Vultur*	The Eagle }	15	12	23	71
Antinous	Antinous }		3	19	
Delphinus	The Dolphin	10	10	14	18
Equulus, *Equi ſectio*	The Horſe's Head	4	4	6	10
Pegaſus, *Equus*	The Flying Horſe	20	19	38	89
Andromeda	Andromeda	23	23	47	66
Triangulum	The Triangle	4	4	12	16
Aries	The Ram	18	21	27	66
Taurus	The Bull	44	43	51	141
Gemini	The Twins	25	25	38	85
Cancer	The Crab	23	15	29	83
Leo	The Lion }	35	30	49	95
Coma Berenices	Berenice's Hair }		14	21	43
Virgo	The Virgin	32	33	50	110
Libra *Chelæ*	The Scales	17	10	20	51
Scorpius	The Scorpion	24	10	20	44
Sagittarius	The Archer	31	14	22	69
Capricornus	The Goat	28	28	29	51
Aquarius	The Water-bearer	45	41	47	108
Piſces	The Fiſhes	38	36	39	113
Cetus	The Whale	22	21	45	97
Orion	Orion	38	42	62	78
Eridanus, *Fluvius*	Eridanus, *the River*	34	10	27	84
Lepus	The Hare	12	13	16	19
Canis major	The Great Dog	29	13	21	31
Canis minor	The Little Dog	2	2	13	14

The ancient Conſtellations.		*Ptolemy.*	*Tycho.*	*Hevel.*	*Flamſt.*
Argo	The Ship	45	3	4	64
Hydra	The Hydra	27	19	31	60
Crater	The Cup	7	3	10	31
Corvus	The Crow	7	4		9
Centaurus	The Centaur	37			35
Lupus	The Wolf	19			24
Ara	The Altar	7			9
Corona Auſtralis	The Southern Crown	13			12
Piſcis Auſtralis	The Southern Fiſh	18			24

The New Southern Conſtellations.

Columba Naochi	Noah's Dove	10
Robur Carolinum	The Royal Oak	12
Grus	The Crane	13
Phœnix	The Phenix	13
Indus	The Indian	12
Pavo	The Peacock	14
Apus, *Avis Indica*	The Bird of Paradiſe	11
Apis, *Muſca*	The Bee or Fly	4
Chamæleon	The Chameleon	10
Triangulum Auſtralis	The South Triangle	5
Piſcis volans, *Paſſer*	The Flying Fiſh	8
Dorado, *Xiphias*	The Sword Fiſh	6
Toucan	The American Gooſe	9
Hydrus	The Water Snake	10

Hevelius's Conſtellations made out of the unformed Stars.

		Hevelius.	*Flamſt.*
Lynx	The Lynx	19	44
Leo minor	The Little Lion		53
Aſteron and Chara	The Greyhounds	23	25
Cerberus	Cerberus	4	
Vulpecula and Anſer	The Fox and Gooſe	27	35
Scutum Sobieſki	Sobieſki's Shield	7	
Lacerta	The Lizard		16
Camelopardalus	The Camelopard	32	58
Monoceros	The Unicorn	19	31
Sextans	The Sextant	11	41

363. There is a remarkable track round the Heavens, called the *Milky Way*, from its peculiar whiteneſs, which is found, by means of the teleſcope, to be owing to a vaſt number of very ſmall Stars that are ſituated in that part of the hea- *The Milky Way.*

 vens.

vens. This track appears ſingle in ſome parts, in others double.

Lucid Spots. 364. There are ſeveral little whitiſh ſpots in the Heavens, which appear magnified, and more luminous, when ſeen through teleſcopes; yet without any Stars in them. One of theſe is in *Andromeda*'s girdle, and was firſt obſerved *A. D.* 1612, by *Simon Marius:* it has ſome whitiſh rays near its middle, is liable to ſeveral changes, and is ſometimes inviſible. Another is near the Ecliptic, between the head and bow of *Sagittarius:* it is ſmall, but very luminous. A third is on the back of the *Centaur*, which is too far ſouth to be ſeen in *Britain.* A fourth, of a ſmaller ſize, is before *Antinous*'s right foot, having a ſtar in it, which makes it appear more bright. A fifth is in the Conſtellation of *Hercules*, between the Stars ζ and η, which ſpot, though but ſmall, is viſible to the bare eye, if the Sky be clear, and the Moon abſent.

Cloudy Stars. 365. *Cloudy Stars* are ſo called from their miſty appearance. They look like dim Stars to the naked eye; but through a teleſcope they appear broad illuminated parts of the Sky; in ſome of which is one Star, in others more. Five of theſe are mentioned by *Ptolemy*. 1. One at the extremity of the right hand of *Perſeus*. 2. One in the middle of the *Crab*. 3. One unformed, near the Sting of the *Scorpion*. 4. The eye of *Sagittarius*. 5. One in the head of *Orion*. In the firſt of theſe appear more Stars through the teleſcope than in any of the reſt, although 21 have been counted in the head of *Orion*, and above 40 in that of the *Crab*. Two are viſible in the eye of *Sagittarius* without a teleſcope, and ſeveral more with it. *Flamſtead* obſerved a cloudy Star in the bow of *Sagittarius*, containing many ſmall Stars: and the Star *d* above *Sagittarius*'s right ſhoulder is encompaſſed with ſeveral more. Both *Caſſini* and *Flamſtead* diſcovered one between the *Great* and *Little Dog*, which is very full of *Stars* viſible only by the teleſcope.

telescope. The two whitish Spots near the South Pole, called the *Magellanic Clouds* by Sailors, which to the bare eye resemble part of the Milky Way, appear through telescopes to be a mixture of small Clouds and Stars. But the most remarkable of all the cloudy Stars is that in the middle of *Orion's Sword*, where seven Stars (of which three are very close together) seem to shine through a cloud, very lucid near the middle, but faint and ill defined about the edges. It looks like a gap in the sky, through which one may see (as it were) part of a much brighter region. Although most of these spaces are but a few minutes of a degree in breadth, yet, since they are among the fixed Stars, they must be spaces larger than what is occupied by our Solar System; and in which there seems to be a perpetual uninterrupted day among numberless Worlds, which no human art ever can discover. Magellanic Clouds.

366. Several Stars are mentioned by ancient Astronomers, which are not now to be found; and others are now visible to the bare eye which are not recorded in the ancient catalogue. *Hipparchus* observed a new Star about 120 years before CHRIST; but he has not mentioned in what part of the Heavens it was seen, although it occasioned his making a Catalogue of the Stars; which is the most ancient that we have. Changes in the Heavens.

The first *New Star* that we have any good account of, was discovered by *Cornelius Gemma* on the 8th of *November*, A. D. 1572, in the Chair of *Cassiopea*. It surpassed *Sirius* in brightness and magnitude; and was seen for 16 months successively. At first it appeared bigger than *Jupiter* to some eyes, by which it was seen at mid-day; afterwards it decayed gradually both in magnitude and lustre, until *March* 1573, when it became invisible. New Stars.

On the 13th of *August* 1596, *David Fabricius* observed the *Stella Mira*, or wonderful Star, in the *Neck* of the *Whale*; which has been since found to appear and disappear periodically seven times in ſix years, continuing in the greateſt luſtre for 15 days together; and is never quite extinguiſhed.

In the year 1600, *William Janſenius* diſcovered a changeable Star in the *Neck* of the *Swan*; which, in time, became ſo ſmall as to be thought to diſappear entirely, till the years 1657, 1658, and 1659, when it recovered its former luſtre and magnitude; but ſoon decayed, and is now of the ſmalleſt ſize.

In the year 1604, *Kepler* and ſeveral of his friends ſaw a new Star near the heel of the right foot of *Serpentarius*, ſo bright and ſparkling, that it exceeded any thing they had ever ſeen before; and took notice that it was every moment changing into ſome of the colours of the rainbow, except when it was near the Horizon, at which time it was generally white. It ſurpaſſed *Jupiter* in magnitude, which was near it all the month of *October*, but eaſily diſtinguiſhed from *Jupiter* by the ſteady light of that Planet. It diſappeared between *October* 1605, and the *February* following, and has not been ſeen ſince that time.

In the year 1670, *July* 15, *Hevelius* diſcovered a new Star, which in *October* was ſo decayed as to be ſcarce perceptible. In *April* following it regained its luſtre, but wholly diſappeared in *Auguſt*. In *March* 1672, it was ſeen again, but very ſmall; and has not been viſible ſince.

In the year 1686, a new Star was diſcovered by *Kirch*, which returns periodically in 404 days.

In the year 1672, *Caſſini* ſaw a Star in the *Neck* of the *Bull*, which he thought was not viſible in *Tycho*'s time; nor when *Bayer* made his Figures.

Cannot be Comets.

367. Many Stars, beſide thoſe above mentioned, have been obſerved to change their magnitudes; and as none of them could ever be perceived to have tails, it is plain they could not be Comets; eſpecially as they had no Parallax, even when largeſt and brighteſt. It would ſeem that the periodical Stars have vaſt cluſters of dark ſpots, and very ſlow

ſlow rotations on their Axes; by which means, they muſt diſappear when the ſide covered with ſpots is turned toward us. And as for thoſe which break out all of a ſudden with ſuch luſtre, it is by no means improbable that they are Suns whoſe fuel is almoſt ſpent, and again ſupplied by ſome of their Comets falling upon them, and occaſioning an uncommon blaze and ſplendour for ſome time: which indeed appears to be the greateſt uſe of the cometary part of any ſyſtem *.

Some Stars change their places.

Some of the Stars, particularly *Arcturus*, have been obſerved to change their places above a minute of a degree with reſpect to others. But whether this be owing to any real motion in the Stars themſelves, muſt require the obſervations of many ages to determine. If our Solar Syſtem changes its place, with regard to abſolute ſpace, this muſt in proceſs of time occaſion an apparent change in the diſtances of the Stars from each other: and in ſuch a caſe, the places of the neareſt Stars to us being more affected than thoſe which are very remote, their relative poſitions muſt ſeem to alter, though the Stars themſelves were really immoveable. On the other hand, if our own Syſtem be at reſt, and any of the Stars in real motion, this muſt vary their poſitions; and the more ſo, the nearer

* M. *Maupertuis*, in his diſſertation on the figures of the Celeſtial Bodies (p. 61—63), is of opinion that ſome Stars, by their prodigious quick rotations on their Axes, may not only aſſume the figures of oblate ſpheroids, but that, by the great centrifugal force, ariſing from ſuch rotations, they may become of the figures of mill-ſtones; or be reduced to flat circular planes, ſo thin as to be quite inviſible when their edges are turned toward us; as Saturn's Ring is in ſuch poſitions. But when any eccentric Planets or Comets go round any flat Star, in Orbits much inclined to its Equator, the attraction of the Planets or Comets in their Perihelions muſt alter the inclination of the Axis of that Star; on which account it will appear more or leſs large and luminous, as its broad ſide is more or leſs turned toward us. And thus he imagines we may account for the apparent changes of magnitude and luſtre in thoſe Stars, and likewiſe for their appearing and diſappearing.

they are to us, or ſwifter their motions are; or the more proper the direction of their motion is for our perception.

The Ecliptic leſs oblique now to the Equator than formerly.

368. The obliquity of the Ecliptic to the Equinoctial is found at preſent to be above the third part of a degree leſs than *Ptolemy* found it. And moſt of the obſervers after him found it to decreaſe gradually down to *Tycho*'s time. If it be objected, that we cannot depend on the obſervations of the ancients, becauſe of the incorrectneſs of their inſtruments; we have to anſwer, that both *Tycho* and *Flamſtead* are allowed to have been very good obſervers; and yet we find that *Flamſtead* makes this obliquity 2½ minutes of a degree leſs than *Tycho* did, about 100 years before him: and as *Ptolemy* was 1324 years before *Tycho*, ſo the gradual decreaſe anſwers nearly to the difference of time between theſe three Aſtronomers. If we conſider, that the Earth is not a perfect ſphere, but an oblate ſpheroid, having its Axis ſhorter than its equatorial diameter; and that the Sun and Moon are conſtantly acting obliquely upon the greater quantity of matter about the Equator, pulling it, as it were, toward a nearer and nearer co-incidenee with the Ecliptic; it will not appear improbable that theſe actions ſhould gradually diminiſh the Angle between thoſe Planes. Nor is it leſs probable that the mutual attraction of all the Planets ſhould have a tendency to bring their Orbits to a co-incidence: but this change is too ſmall to become ſenſible in many ages.

CHAP.

CHAP. XXI.

Of the Division of Time. A perpetual Table of New Moons. The Times of the Birth and Death of CHRIST. *A Table of remarkable Æras or Events.*

369. THE parts of Time are *Seconds, Minutes, Hours, Days, Years, Cycles, Ages*, and *Periods*.

370. The original ſtandard, or integral meaſure of time, is a Year; which is determined by the Revolution of ſome Celeſtial Body in its Orbit, viz. the *Sun* or *Moon*. A Year.

371. The Time meaſured by the Sun's Revolution in the Ecliptic, from any Equinox or Solſtice to the ſame again, is called the *Solar* or *Tropical Year*, which contains 365 days, 5 hours, 48 minutes, 57 ſeconds; and is the only proper or natural year, becauſe it always keeps the ſame ſeaſons to the ſame months. Tropical Year.

372. The quantity of time meaſured by the Sun's Revolution as from any fixed Star to the ſame Star again, is called the *Sydereal Year*; which contains 365 days, 6 hours, 9 minutes, 14½ ſeconds; and is 20 minutes, 17½ ſeconds longer than the true Solar Year. Sydereal Year.

373. The time meaſured by twelve Revolutions of the Moon, from the Sun to the Sun again, is called the *Lunar Year*; it contains 354 days, 8 hours, 48 minutes, 36 ſeconds; and is therefore 10 days, 21 hours, 0 minutes, 21 ſeconds ſhorter than the Solar Year. This is the foundation of the Epact. Lunar Year.

374. The *Civil Year* is that which is in common uſe among the different nations of the world; of which, ſome reckon by the Lunar, but moſt by the Solar. The Civil Solar Year contains 365 days, for three years running, which are called *Common Years*; and then comes in what is called the *Biſſex-* Civil Year.

tile or *Leap-year*, which contains 366 days. This is alſo called the *Julian Year*, on account of *Julius Cæſar*, who appointed the intercalary day every fourth year, thinking thereby to make the Civil and Solar Year keep pace together. And this day, being added to the 23d of *February*, which in the *Roman* Calendar was the ſixth of the Calends of *March*, that ſixth day was twice reckoned, or the 23d and 24th were reckoned as one day; and was called *Bis ſextus dies*, and thence came the name *Biſſextile* for that year. But in our common Almanacks this day is added at the end of *February*.

Lunar Year.

375. The *Civil Lunar Year* is alſo common or intercalary. The common Year conſiſts of 12 Lunations, which contain 354 days; at the end of which, the year begins again. The *Intercalary*, or *Embolimic* Year, is that wherein a month was added to adjuſt the Lunar Year to the Solar. This method was uſed by the *Jews*, who kept their account by the Lunar Motions. But by intercalating no more than a month of 30 days, which they called *Ve-Adar*, every third year they fell $3\frac{1}{4}$ days ſhort of the Solar Year in that time.

Roman Year.

376. The *Romans* alſo uſed the *Lunar Embolimic Year* at firſt, as it was ſettled by *Romulus* their firſt King, who made it to conſiſt only of ten months or Lunations; which fell 61 days ſhort of the Solar Year, and ſo their year became quite vague and unfixed; for which reaſon they were forced to have a Table publiſhed by the High-Prieſt, to inform them when the ſpring and other ſeaſons began. But *Julius Cæſar*, as already mentioned, § 374, taking this troubleſome affair into conſideration, reformed the Calendar, by making the year to conſiſt of 365 days, 6 hours.

The original of the Gregorian or *New Stile.*

377. The year thus ſettled, is what was uſed in *Britain* till *A.D.* 1752: but as it is ſomewhat more than 11 minutes longer than the *Solar Tropical Year*, the times of the Equinoxes go backward, and fall earlier by one day in about 130 years. In the time

of the *Nicene Council* (A. D. 325), which was 1439 years ago, the Vernal Equinox fell on the 21ſt of *March:* and if we divide 1444 by 130, it will quote 11, which is the number of days the Equinox has fallen back ſince the Council of *Nice*. This cauſing great diſturbances, by unfixing the times of the celebtation of *Eaſter*, and conſequently of all the other moveable Feaſts, Pope *Gregory* the XIII. in the year 1582, ordered ten days to be at once ſtruck out of that year; and the next day after the fourth of *October* was called the fifteenth. By this means the Vernal Equinox was reſtored to the 21ſt of *March*; and it was endeavoured, by the omiſſion of three intercalary days in 400 years, to make the Civil or Political year keep pace with the Solar for the time to come. This new form of the year is called the *Gregorian Account*, or *New Stile*; which is received in all countries where the Pope's authority is acknowledged, and ought to be in all places where truth is regarded.

378. The principal diviſion of the year is into *Months*, which are of two ſorts, namely, *Aſtronomical* and *Civil*. The Aſtronomical month is the time in which the Moon runs through the *Zodiac*, and is either *Periodical* or *Synodical*. The Periodical Month is the time ſpent by the Moon in making one complete Revolution from any point of the Zodiac to the ſame again; which is $27^d\ 7^h\ 43^m$. The Synodical Month, called a *Lunation*, is the time contained between the Moon's parting with the Sun at a Conjunction, and returning to him again; which is $29^d\ 12^h\ 44^m$. The Civil Months are thoſe which are framed for the uſes of civil life; and are different as to their names, number of days, and times of beginning, in ſeveral different Countries. The firſt month of the *Jewiſh Year* fell, according to the Moon, in our *Auguſt* and *September*, Old Stile; the ſecond in *September* and *October*; and ſo on. The firſt month of the *Egyptian Year* began on the 29th of our Months.

our *Auguſt*. The firſt month of the *Arabic* and *Turkiſh Year* began the 16th of *July*. The firſt month of the *Grecian Year* fell, according to the Moon, in *June* and *July*, the ſecond in *July* and *Auguſt*, and ſo on, as in the following Table.

379. A month is divided into four parts called *Weeks*, and a week into ſeven parts called *Days*; ſo that in a *Julian* year there are 13 ſuch Months, or 52 Weeks, and one Day over. The *Gentiles* gave the names of the Sun, Moon, and Planets, to the Days of the Week. To the firſt, the Name of the *Sun*; to the ſecond, of the *Moon*; to the third, of *Mars*; to the fourth, of *Mercury*; to the fifth, of *Jupiter*; to the ſixth, of *Venus*; and to the ſeventh, of *Saturu*.

N°	The *Jewiſh* year.		Days
1	Tiſri — — —	Aug.—Sept.	30
2	Marcheſvan — —	Sept.—Oct.	29
3	Caſleau — — —	Oct.—Nov.	30
4	Tebeth — — —	Nov.—Dec.	29
5	Shebat — — —	Dec.—Jan.	30
6	Adar — — —	Jan.—Feb.	29
7	Niſan *or* Abib - —	Feb.—Mar.	30
8	Jiar — — — —	Mar.—Apr.	29
9	Sivan — — —	Apr.—May	30
10	Tamuz — — —	May—June	29
11	Ab — — — —	June—July	30
12	Elul - — — —	July—Aug.	29
	Days in the year — —		354

In the *Embolimic* year after *Adar* they added a month called *Ve-Adar* of 30 days.

N°	The *Egyptian* year.			Days
1	Thoth — — —	August	29	30
2	Paophi — — —	September	28	30
3	Athir — — —	October	28	30
4	Chojac — — —	November	27	30
5	Tybi — — —	December	27	30
6	Mechir — — —	January	26	30
7	Phamenoth — —	February	25	30
8	Parmuthi — —	March	27	30
9	Pachon — — —	April	26	30
10	Payni — — —	May	26	30
11	Epiphi — — —	June	25	30
12	Mesori — — —	July	25	30
	Epagomenæ or days added —			5
	Days in the year — —			365

N°	The *Arabic* and *Turkish* year.			Days
1	Muharram — —	July	16	30
2	Saphar — — —	August	15	29
3	Rabia I. - — —	September	13	30
4	Rabia II. - — —	October	13	29
5	Jomada I. — —	November	11	30
6	Jomada II. — —	December	11	29
7	Rajab — — —	January	9	30
8	Shasban - — —	February	8	29
9	Ramadam — —	March	9	30
10	Shawal — — —	April	8	29
11	Dulhaadah — —	May	7	30
12	Dulheggia — —	June	5	29
	Days in the year — —			354

The *Arabians* add 11 days at the end of every year, which keep the same months to the same seasons.

N°	The ancient *Grecian* year.		Days
1	Hecatombæon	June—July	30
2	Metagitnion	July—Aug.	29
3	Boëdromion	Aug.—Sept.	30
4	Pyanepſion	Sept.—Oct.	29
5	Maimacterion	Oct.—Nov.	30
6	Poſideon	Nov.—Dec.	29
7	Gamelion	Dec.—Jan.	30
8	Antheſterion	Jan.—Feb.	29
9	Elaphebolion	Feb.—Mar	30
10	Municheon	Mar.—Apr.	29
11	Thargelion	Apr.—May	30
12	Schirrophorion	May—June	29
	Days in the year		354

Days. 380. A *Day* is either *Natural* or *Artificial.* The Natural Day contains 24 hours; the Artificial, the time from Sun-riſe to Sun-ſet. The Natural Day is either *Aſtronomical* or *Civil.* The Aſtronomical Day begins at Noon, becauſe the increaſe and decreaſe of Days terminated by the Horizon are very unequal among themſelves; which inequality is likewiſe augmented by the inconſtancy of the horizontal Refractions § 183; and therefore the Aſtronomer takes the Meridian for the limit of diurnal Revolutions; reckoning Noon, that is, the inſtant when the Sun's center is on the Meridian, for the beginning of the Day. The *Britiſh*, *French*, *Dutch*, *Germans*, *Spaniards*, *Portugueſe*, and *Egyptians*, begin the Civil Day at Midnight: the ancient *Greeks*, *Jews*, *Bohemians*, *Sileſians*, with the modern *Italians*, and *Chineſe*, begin it at Sun-ſetting: and the ancient *Babylonians*, *Perſians*, *Syrians*, with the modern *Greeks*, at Sun-riſing.

Hours. 381. An *Hour* is a certain determinate part of the Day, and is either equal or unequal. An equal Hour is the 24th part of a mean natural Day, as ſhewn

ſhewn by well-regulated Clocks and watches; but theſe hours are not quite equal as meaſured by the returns of the Sun to the Meridian, becauſe of the obliquity of the Ecliptic and Sun's unequal motion in it, § 224—245. Unequal Hours are thoſe by which the Artificial Day is divided into twelve Parts, and the Night into as many.

382. An Hour is divided into 60 equal parts called *Minutes*, a Minute into 60 equal parts called *Seconds*, and theſe again into 60 equal parts called *Thirds*. The *Jews*, *Chaldeans*, and *Arabians*, divide the Hour into 1080 equal parts called *Scruples*; which number contains 18 times 60, ſo that one minute contains 18 Scruples. Minutes, Seconds, Thirds, and Scruples.

383. A *Cycle* is a perpetual round, or circulation of the ſame parts of time of any ſort. The *Cycle of the Sun* is a revolution of 28 years, in which time the days of the months return again to the ſame days of the week; the Sun's Place to the ſame Signs and Degrees of the Ecliptic on the ſame months and days, ſo as not to differ one degree in 100 years; and the Leap-years begin the ſame courſe over again with reſpect to the days of the week on which the days of the months fall. The *Cycle of the Moon*, commonly called the *Golden Number*, is a revolution of 19 years; in which time, the Conjunctions, Oppoſitions, and other Aſpects of the Moon, are within an hour and half of being the ſame as they were on the ſame days of the months 19 years before. The *Indiction* is a revolution of 15 years, uſed only by the *Romans* for indicating the times of certain payments made by the ſubjects to the Republic: it was eſtabliſhed by *Conſtantine*, A. D. 312. Cycles of the Sun, Moon, and Indiction.

384. The year of our SAVIOUR's Birth, according to the vulgar Æra, was the 9th year of the Solar Cycle; the firſt year of the Lunar Cycle; and the 312th year after his birth was the firſt year of the *Roman* Indiction. Therefore, to find the year of the Solar Cycle, add 9 to any given year of To find the Years of theſe Cycles.

of CHRIST, and divide the ſum by 28, the Quotient is the number of Cycles elapſed ſince his birth, and the remainder is the Cycle for the given year: if nothing remain, the Cycle is 28. To find the Lunar Cycle, add 1 to the given year of CHRIST, and divide the ſum by 19; the Quotient is the number of Cycles elapſed in the interval, and the remainder is the Cycle for the given year: if nothing remain, the Cycle is 19. Laſtly, ſubtract 312 from the given year of CHRIST, and divide the remainder by 15; and what remains after this diviſion is the Indiction for the given year: if nothing remain, the indiction is 15.

The deficiency of the Lunar Cycle, and conſequence thereof.

385. Although the above deficiency in the Lunar Cycle of an hour and half every 19 years be but ſmall, yet in time it becomes ſo ſenſible as to make a whole natural Day in 310 years. So that, although this Cycle be of uſe, when the Golden Numbers are rightly placed againſt the days of the months in the Calendar, as in our *Common Prayer Books*, for finding the days of the mean Conjunctions or Oppoſitions of the Sun and Moon, and conſequently the time of *Eaſter*; it will only ſerve for 310 years, *Old Stile*. For as the New and Full Moons anticipate a day in that time, the Golden Numbers ought to be placed one day earlier in the Calendar for the next 310 years to come. Theſe Numbers were rightly placed againſt the days of New Moon in the Calendar, by the Council of *Nice*, A. D. 325; but the anticipation which has been neglected ever ſince, is now grown almoſt into 5 days; and therefore all the Golden Numbers ought now to be placed 5 days higher in the Calendar for the *Old Stile* than they were at the time of the ſaid Council; or ſix days lower for the *New Stile*, becauſe at preſent it differs 11 days from the *Old*.

How to find the day of the New Moon by the Golden Number.

386. In the annexed Table, the Golden Numbers under the months ſtand againſt the days of New Moon in the left-hand column, for the *New*

Stile;

Days.	*Jan.*	*Feb.*	*March*	*April*	*May*	*June*	*July*	*August*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
1	9		9	17	17	6				11		19
2		17			6	14	14	3	11		19	
3	17	6	17	6			3	11		19	8	8
4	6		6	14	14	3			19	8		16
5		14			3	11	11	19	8		16	
6	14	3	14	3			19			16	5	5
7	3		3	11	11	19		8	16			13
8		11			19	8	8	16	5	5	13	
9	11	19	11	19						13		2
10			19	8	8	16	16	5	13		2	10
11	19	8					5	13	2	2	10	
12	8	16	8	16	16	5				10		18
13					5	13	13	2	10		18	7
14	16	5	16	5			2	10	18	18	7	
15	5		5	13	13	2				7		15
16		13			2	10	10	18	7		15	
17	13	2	13	2			18	7		15	4	4
18	2		2	10	10	18			15			12
19		10			18	7	7	15	4	4	12	
20	10	18	10	18			15			12	1	1
21	18		18	7	7	15		4	12			9
22		7			15	4	4	12	1	1	9	
23	7	15	7	15			12			9	17	17
24			15	4	4	12		1	9			6
25	15	4			12		1	9	17	17	6	
26	4		4	12		1				6		14
27		12		1	1	9	9	17	6		14	
28	12		12		9		17	6	14	14	3	3
29	1		1	9		17				3		11
30					17	6	6	14	3		11	
31	9		9				14	3		11		19

Stile; adapted chiefly to the ſecond year after Leap-year, as being the neareſt mean for all the four; and will ſerve till the year 1900. Therefore, to find the day of New Moon in any month of a given year till that time, look for the Golden Number of that year under the deſired month, and againſt it, you have the day of New Moon in the left-hand column. Thus, ſuppoſe it were required to find the day of New Moon in *September*, 1757; the Golden Number for that year is 10, which I look for under *September*, and right againſt it in the left-hand column I find 13, which is the day of New Moon in that month. *N. B.* If all the Golden Numbers, except 17 and 6, were ſet one day lower in the Table, it would ſerve from the beginning of the year 1900 till the end of the year 2199. The firſt Table after this Chapter ſhews the Golden Number for 4000 years after the birth of CHRIST; by looking for the even hundreds of any given year at the left hand, and for the reſt to make up that year at the head of the Table; and where the columns meet, you have the Golden Number (which is the ſame both in *Old* and *New Stile*) for the given year. Thus, ſuppoſe the Golden Number was wanted for the year 1757; I look for 1700 at the left hand of the Table, and for 57 at the top of it; then guiding my eye downward from 57 to over againſt 1700, I find 10, which is the Golden Number for that year.

A perpetual Table of the time of New Moon to the neareſt hour for the *Old Stile*.

387. But becauſe the Lunar Cycle of 19 years ſometimes includes five Leap-years, and at other times only four, this Table will ſometimes vary a day from the truth in Leap-years after *February*. And it is impoſſible to have one more correct, unleſs we extend it to four times 19 or 76 years; in which there are 19 Leap-years without a remainder. But even then to have it of perpetual uſe, it muſt be adapted to the *Old Stile*; becauſe in every centurial year not diviſible by 4, the regular courſe of Leap-years is interrupted in the *New*; as will be

be the case in the year 1800. Therefore, upon the regular *Old Stile* plan, I have computed the following Table of the mean times of all the New Moons to the nearest hour for 76 years; beginning with the year of CHRIST 1724, and ending with the year 1800.

This Table may be made perpetual, by deducting 6 hours from the time of New Moon in any given year and month from 1724 to 1800, in order to have the mean time of New Moon in any year and month 76 years afterward; or deducting 12 hours for 152 years, 18 hours for 228 years, and 24 hours for 304 years: because in that time the changes of the Moon anticipate almost a complete natural day. And if the like number of hours be added for so many years past, we shall have the mean time of any New Moon already elapsed. Suppose, for example, the mean time of Change was required for *January* 1802; deduct 76 years, and there remains 1726, against which, in the following Table, under *January*, I find the time of New Moon was on the 21st day, at 11 in the evening: from which take 6 hours, and there remains the 21st day, at 5 in the evening, for the mean time of Change in *January* 1802. Or, if the time be required for *May*, A. D. 1701, add 76 years, and it makes 1777, which I look for in the Table, and against it, under *May*, I find the New Moon in that year falls on the 25th day, at 9 in the evening; to which add 6 hours and it gives the 26th day, at 3 in the morning, for the time of New Noon in *May*, A. D. 1701. By this addition for time past, or subtraction for time to come, the Table will not vary 24 hours from the truth in less than 14592 years. And if, instead of 6 hours for every 76 years, we add or subtract only 5 hours 52 minutes, it will not vary a day in 10 millions of years.

Although this Table is calculated for 76 years only, and according to the *Old Stile*, yet by means of two eafy Equations it may be made to anfwer as exactly to the *New Stile*, for any time to come. Thus, becaufe the year 1724 in this Table is the firft year of the Cycle for which it is made; if from any year of CHRIST after 1800 you fubtract 1723, and divide the overplus by 76, the quotient will fhew how many entire Cycles of 76 years are elapfed fince the beginning of the Cycles here provided for; and the remainder will fhew the year of the current Cycle anfwering to the given year of CHRIST. Hence if the remainder be 0, you muft inftead thereof put 76, and leffen the quotient by unity.

Then, look in the left-hand column of the Table for the number in your remainder, and againft it you will find the times of all the mean New Moons in that year of the prefent Cycle. And whereas in 76 *Julian* years the Moon anticipates 5 hours 52 minutes, if therefore thefe 5 hours 52 minutes be multiplied by the above found Quotient, that is, by the number of entire Cycles paft; the product fubtracted from the times in the Table will leave the corrected times of the New Moons to the *Old Stile*; which may be reduced to the *New Stile* thus:

Divide the number of entire hundreds in the given year of CHRIST by 4, multiply this quotient by 3, to the product add the remainder, and from their fum fubtract 2: this laft remainder denotes the number of days to be added to the times above corrected, in order to reduce them to the *New Stile*. The reafon of this is, that every 400 years of the *New Stile* gains 3 days upon the *Old Stile*: one of which it gains in each of the centurial years fucceeding that which is exactly divifible by 4 without a remainder; but then, when you have found the days fo gained, 2 muft be fubtracted from their number on account of the rectifications made in the Calendar by the Council of *Nice*, and fince by

Pope *Gregory*. It muft alfo be obferved, that the additional days found as above directed, do not take place in the centurial Years which are not multiples of 4 till *February* 29th, *Old Stile*, for on that day begins the difference between the *Stiles*; till which day, therefore, thofe that were added in the preceding years muft be ufed. The following Example will make this accommodation plain.

Required the mean time of New Moon in June, A.D. 1909, *N. S.*

From 1909 take 1723 years, and there remains	186
Which, divided by 76, gives the quotient 2 and the remainder —	34
Then, againft 34 in the Table is *June* - —	$5^d\ 8^h\ 0^m$ Afternoon
And $5^h\ 52^m$ multiplied by 2 make to be fubtr. —	11 44
Remains the mean time according to the *Old Stile*, *June* — —	$5^d\ 8^h\ 16^m$
Entire hundreds in 1909 are 19, which divide by 4, quotes — —	4
And leaves a remainder of	3
Which quotient multiplied by 3 makes 12, and the remainder added makes — —	15
From which fubtract 2, and there remains —	13
Which number of days added to the above time, *Old Stile*, gives *June* —	$18^d\ 8^h\ 16^m$ Morn. *N. S.*

So the mean time of New Moon in *June*, 1909, *New Stile* is the 18th day, at 16 minutes paſt 8 in the Morning.

If 11 days be added to the time of any New Moon in this Table, it will give the time of that New Moon according to the *New Stile* till the year 1800. And if 14 days 18 hours 22 minutes be added to the mean time of New Moon in either *Stile*, it will give the mean time of the next Full Moon according to that *Stile*.

A Table

A TABLE *shewing the times of all the mean Changes of the Moon, to the nearest Hour, through four Lunar Periods, or 76 years.* M *signifies morning,* A *afternoon.*

Years of the Cyc.	A.D.	January D.	January H.	February D.	February H.	March D.	March H.	April D.	April H.
1	1724	14	5 A	13	5M	13	6 A	12	7M
2	1725	3	2M	1	2 A	3	3M	1	4 A
3	1726	21	11 A	20	11M	21	12 A	20	1 A
4	1727	11	8M	9	9 A	11	9M	9	10 A
5	1728	30	6M	28	7 A	29	7M	27	8 A
6	1729	18	2 A	17	3M	18	4 A	17	4M
7	1730	7	11 A	6	0 A	8	1M	6	1 A
8	1731	26	9 A	25	10M	26	10 A	15	11M
9	1732	16	5M	14	6 A	15	7M	23	8 A
10	1733	4	2 A	3	3M	4	4 A	3	4M
11	1734	23	0 A	22	1M	23	1 A	22	2M
12	1735	12	9 A	11	9M	12	10 A	11	11M
13	1736	2 31	5M 6 A	—	—	1 30	7M 8 A	29	9M
14	1737	20	3M	18	4 A	20	4M	18	5 A
15	1738	9	11M	7	12 A	9	1 A	8	1M
16	1739	28	9M	26	10 A	28	1M	26	12 A
17	1740	17	6 A	16	7M	16	8 A	15	9M
18	1741	6	3M	4	4 A	6	4M	4	5 A
19	1742	24	12 A	23	1 A	25	2M	23	3 A
20	1743	14	9M	12	10 A	14	11M	12	12 A
21	1744	3	6 A	2	7M	2	8 A	1 30	9M 9 A
22	1745	21	4 A	20	5M	21	5 A	20	6M
23	1746	10	12 A	9	1 A	11	2M	9	3 A
24	1747	29	10 A	28	11M	29	11 A	28	0 A
25	1748	19	6M	17	7 A	18	8M	16	9 A
26	1749	7	3 A	6	4M	7	5 A	6	6M

A Table *of the mean New Moons, &c.*

Yrs. of the Cyc.	A.D.	*May* D.	*May* H.	*June* D.	*June* H.	*July* D.	*July* H.	*August* D.	*August* H.
1	1724	11	8 A	10	8M	9	9 A	8	10M
2	1725	1 30	4M 5 A	29	6M	28	7 A	27	8M
3	1726	20	1M	18	2 A	18	3M	16	4 A
4	1727	9	11M	7	12 A	7	0 A	6	1M
5	1728	27	8M	25	9 A	25	10M	23	11 A
6	1729	16	5 A	15	6M	14	7 A	12	7M
7	1730	6	2M	4	3 A	4	3M	2	4 A
8	1731	24	11 A	23	0 A	23	1M	21	2 A
9	1732	13	8M	11	9 A	11	10M	9	11 A
10	1733	2	5 A	1 30	6M 7 A	30	8M	28	8 A
11	1734	21	2 A	20	3M	19	4 A	18	5M
12	1735	10	11 A	9	0 A	9	1M	7	2 A
13	1736	28	9 A	27	10M	26	11 A	25	0 A
14	1737	18	5M	16	6 A	16	7M	14	8 A
15	1738	7	2 A	6	3 A	5	4 A	4	5M
16	1739	26	0 A	25	1M	24	2 A	23	3M
17	1740	14	9 A	13	10M	12	11 A	11	0 A
18	1741	4	5M	2	6 A	2 31	7M 7 A	30	8M
19	1742	23	3M	21	4 A	21	5M	19	6 A
20	1743	12	0 A	11	1M	10	2 A	9	3M
21	1744	30	10M	28	11 A	28	0 A	26	12 A
22	1745	19	6 A	18	7M	17	8 A	16	8M
23	1746	9	3M	7	4 A	7	5M	5	6 A
24	1747	27	12 A	26	1 A	26	2M	24	3 A
25	1748	16	9M	14	10 A	14	11M	12	12 A
26	1749	5	6 A	4	7M	3	8 A	2 31	9M 9 A

A TABLE *of the mean New Moons*, &c.

Yrs. of the Cyc.	A.D.	September D.	September H.	October D.	October H.	November D.	November H.	December D.	December H.
1	1724	6	10 A	6	11 M	4	12 A	4	1 A
2	1725	25	8 A	25	9 M	23	10 A	23	11 M
3	1726	15	5 M	14	5 A	13	6 M	12	7 A
4	1727	4	1 A	4	2 M	2	3 A	2 31	4 M 5 A
5	1728	22	11 M	21	12 A	20	1 A	20	2 M
6	1729	11	8 A	11	9 M	9	10 A	9	11 M
7	1730	2 30	5 M 6 A	30	7 M	28	8 A	28	9 M
8	1731	20	2 M	19	3 A	18	4 M	17	5 A
9	1732	8	11 M	7	12 A	6	1 A	6	2 M
10	1733	27	M	26	10 A	25	11 M	24	11 A
11	1734	16	5 A	16	6 M	14	7 A	14	8 M
12	1735	6	2 M	5	3 A	4	4 M	3	5 A
13	1736	23	12 A	23	1 A	22	2 M	21	3 A
14	1737	13	8 M	12	9 A	11	10 M	10	11 A
15	1738	2	5 A	2 31	6 M 7 A	30	8 M	29	8 A
16	1739	21	3 A	21	4 M	19	5 A	19	6 M
17	1740	9	12 A	9	1 A	8	2 M	7	3 A
18	1741	28	9 A	28	10 M	26	11 A	26	11 M
19	1742	18	6 M	17	7 A	16	8 M	15	9 A
20	1743	7	3 A	7	4 M	5	5 A	5	6 M
21	1744	25	1 A	25	2 M	23	3 A	23	3 M
22	1745	14	9 A	14	10 M	12	11 A	12	0 A
23	1746	4	6 M	3	7 A	2	8 M	1 31	9 A 10 M
24	1747	2	3 M	22	4 A	21	5 M	20	6 A
25	1748	11	0 A	11	1 M	9	2 A	9	3 M
26	1749	30	10 M	29	11 A	28	0 A	27	12 A

A TABLE *of the mean New Moons continued.*

Yrs. of the Cyc.	A.D.	January D.	January H.	February D.	February H.	March D.	March H.	April D.	April H.
27	1750	26	1 A	25	2 M	26	3 A	25	4 M
28	1751	15	10 A	14	11 M	15	11 A	14	0 A
29	1752	5	6 M	3	7 A	4	8 M	2	9 A
30	1753	23	4 M	21	5 A	23	6 M	21	7 A
31	1754	12	1 A	11	2 M	12	3 A	11	4 M
32	1755	1 31	10 A 11 M	—	—	1 31	11 A 0 A	29	12 A
33	1756	20	7 A	19	8 M	19	9 A	18	9 M
34	1757	9	4 M	7	5 A	9	6 M	7	7 A
35	1758	28	2 M	26	3 A	28	3 M	26	4 A
36	1759	17	10 M	15	11 A	17	0 A	16	1 M
37	1760	6	7 A	5	8 M	5	9 A	4	10 M
38	1761	24	5 A	23	6 M	24	7 A	23	8 M
39	1762	14	2 M	12	3 A	14	3 M	12	4 A
40	1763	3	11 M	1	12 A	3	0 A	2	1 M
41	1764	22	8 M	20	9 A	21	10 M	19	11 A
42	1765	10	5 A	9	6 M	10	6 A	9	7 M
43	1766	29	2 A	28	3 A	29	4 A	28	5 M
44	1767	18	11 A	17	12 A	19	1 M	17	2 A
45	1768	8	8 M	6	9 A	7	10 M	5	11 A
46	1769	26	6 M	24	7 A	26	7 M	24	8 A
47	1770	15	2 A	14	3 M	15	4 A	14	5 M
48	1771	4	11 M	3	0 A	5	1 M	3	2 A
49	1772	23	9 A	22	10 M	22	10 A	21	11 M
50	1773	12	5 M	10	6 A	12	7 M	10	8 A
51	1774	1 31	2 A 3 M	—	—	1 31	4 A 5 M	29	5 A
52	1775	20	0 A	19	1 M	20	2 A	19	3 M
53	1776	9	9 A	8	10 M	8	10 A	7	11 M

A TABLE *of the mean New Moons continued.*

Yrs. of the Cyc.	A.D.	*May* D.	*May* H.	*June* D.	*June* H.	*July* D.	*July* H.	*August* D.	*August* H.
27	1750	24	4 A	23	5M	22	6 A	21	7M
28	1751	13	12 A	12	1 A	12	2M	10	3 A
29	1752	2 31	9M 10 A	30	11M	29	12 A	28	0 A
30	1753	21	7M	19	8 A	19	9M	17	10 A
31	1754	10	4 A	9	5M	8	6 A	7	7M
32	1755	29	1 A	28	2M	27	3 A	25	3M
33	1756	17	10 A	16	11M	15	12 A	14	1 A
34	1757	7	7M	5	8 A	5	9M	3	10 A
35	1758	26	4M	24	5 A	24	6M	22	7 A
36	1759	15	1 A	14	2M	13	3 A	12	2M
37	1760	3	10 A	2	11M	1 31	12 A 1 A	30	1M
38	1761	22	9 A	21	10M	20	10 A	19	11M
39	1762	12	4M	10	5 A	10	6M	8	7 A
40	1763	1 31	1 A 2M	29	3 A	29	4M	27	4 A
41	1764	19	11M	17	12 A	17	1 A	16	2M
42	1765	8	7 A	7	8M	6	9 A	5	10M
43	1766	27	5 A	26	6M	25	7 A	24	8M
44	1767	17	2M	15	3 A	15	4M	13	5 A
45	1768	5	11M	3	12 A	3	1 A	2 31	2M 2 A
46	1769	24	8M	22	9 A	22	10M	20	11 A
47	1770	13	5 A	12	4M	11	7 A	10	8M
48	1771	3	2M	1	3 A	1 30	4M 5 A	29	5M
49	1772	20	11 A	19	0 A	19	1M	17	2 A
50	1773	10	8M	8	9 A	8	9M	6	10 A
51	1774	29	6M	27	7 A	27	8M	25	8 A
52	1775	18	3 A	17	4M	16	5 A	15	6M
53	1776	6	12 A	5	0 A	5	1M	3	2 A

A TABLE *of the mean New Moons continued.*

Yrs. of the Cyc.	A.D.	September D.	September H.	October D.	October H.	November D.	November H.	December D.	December H.
27	1750	19	7 A	19	8M	17	9 A	17	10M
28	1751	9	3M	8	4 A	7	5M	6	6 A
29	1752	27	1M	26	2 A	25	3M	24	3 A
30	1753	16	10M	15	11 A	14	0 A	14	1M
31	1754	5	7 A	5	8M	3	9 A	3	10M
32	1755	24	4 A	24	5M	22	6 A	22	6M
33	1756	13	1M	12	2 A	11	3M	10	4 A
34	1757	2	10M	1 31	11 A 0 A	30	1M	29	1 A
35	1758	21	7M	20	8 A	19	9M	18	10 A
36	1759	10	4 A	10	5M	8	6 A	8	7M
37	1760	28	2 A	28	3M	26	4 A	26	4M
38	1761	17	11 A	17	0 A	16	1M	15	2 A
39	1762	6	7M	6	8 A	5	9M	4	10 A
40	1763	26	5M	25	6 A	24	7M	23	7 A
41	1764	14	2 A	14	3M	12	4 A	12	5M
42	1765	3	10 A	3	11M	1	12 A	1 31	1 A 1M
43	1766	22	8 A	22	9M	20	10 A	20	11M
44	1767	12	6M	11	6 A	10	7M	9	8M
45	1768	30	3M	29	4 A	28	5M	27	5 A
46	1769	19	1M	18	12 A	17	1 A	17	2M
47	1770	8	8 A	8	9M	6	10 A	6	11M
48	1771	27	6 A	27	7M	25	8 A	25	9M
49	1772	16	2M	15	3 A	14	4M	13	5 A
50	1773	5	11M	4	12 A	3	1 A	3	2M
51	1774	24	9M	23	10 A	22	11M	21	11 A
52	1775	13	6 A	13	7M	11	8 A	11	9M
53	1776	32	2M	1 1	3 A 4M	29	5 A	29	5M

Yrs. of the Cyc.	A.D.	January D.	January H.	February D.	February H.	March D.	March H.	April D.	April H.
54	1777	27	6 A	26	7M	27	8 A	26	9M
55	1778	17	3M	15	4 A	17	5M	15	6 A
56	1779	6	0 A	5	1M	6	2 A	5	3M
57	1780	25	10M	23	11 A	24	11M	22	12 A
58	1781	13	6 A	12	7M	13	8 A	12	9M
59	1782	3	3M	1	4 A	3	5M	1	6 A
60	1783	22	1M	20	2 A	22	2M	20	3 A
61	1784	11	9M	9	10 A	10	11M	8	12 A
62	1785	29	7M	27	8 A	29	9M	27	10 A
63	1786	18	4 A	17	5M	18	5 A	17	6M
64	1787	7	12 A	6	1 A	8	2M	6	3 A
65	1788	26	10 A	25	11M	25	12 A	24	1 A
66	1789	15	7M	13	8 A	15	9M	13	10 A
67	1790	4	4 A	3	5M	4	5 A	3	6M
68	1791	23	1 A	22	2M	23	3 A	22	4M
69	1792	12	10 A	11	11M	11	12 A	10	1 A
70	1793	1 30	7M 8 A			1 30	9M 10 A	29	10M
71	1794	20	5M	18	6 A	20	6M	18	7 A
72	1795	9	1 A	8	2M	9	3 A	8	4M
73	1796	28	11M	26	12 A	27	0 A	26	1M
74	1797	16	7 A	15	8M	16	9 A	15	10M
75	1798	6	4M	4	5 A	6	6M	4	7 A
76	1799	25	2M	23	3 A	25	4M	23	5 A
1	1800	1[illegible]	11M	12	12 A	13	0 A	12	1M

A TABLE of the mean New Moons concluded.

The year 1800 begins a new Cycle.

A TABLE *of the mean New Moons concluded.*

Yrs. of the Cyc.	A.D.	*May*		*June*		*July*		*August*	
		D.	H.	D.	H.	D.	H.	D.	H.
54	1777	25	9 A	24	10M	23	11 A	22	0 A
55	1778	15	6M	13	7 A	13	8M	11	9 A
56	1779	4	3 A	3	4M	2	5 A	1 30	6M 6 A
57	1780	22	0 A	21	1M	20	2 A	19	3 A
58	1781	11	9 A	10	10M	9	11 A	8	0M
59	1782	1 30	6M 7 A	29	8M	28	9 A	27	9M
60	1783	20	3M	18	4 A	18	5M	16	6 A
61	1784	8	0 A	7	1M	6	2 A	5	3M
62	1785	27	10M	25	11 A	25	0 A	24	1M
63	1786	16	6 A	15	7M	14	8 A	13	9M
64	1787	6	3M	4	4 A	4	5M	2	6 A
65	1788	24	1M	22	2 A	22	3M	20	4 A
66	1789	13	10M	11	11 A	11	0 A	10	1M
67	1790	2	6 A	1 30	7M 8 A	30	9M	28	9 A
68	1791	21	4 A	20	5M	19	6 A	18	7M
69	1792	10	1M	8	2 A	8	3M	6	4 A
70	1793	28	11 A	27	0 A	27	1M	25	1 A
71	1794	18	7M	16	8 A	16	9M	14	10 A
72	1795	7	4 A	6	5M	5	6 A	4	7M
73	1796	25	1 A	24	2M	23	3 A	22	4M
74	1797	14	10 A	13	11M	12	12 A	11	1 A
75	1798	4	7M	2	8 A	2 31	9M 10 A	30	10M
76	1799	23	5M	21	6 A	21	6M	19	8 A
1	1800	11	1 A	10	2M	9	3 A	8	4M

A TABLE *of the mean New Moons concluded.*

Yrs. of the Cyc.	A.D.	September D.	September H.	October D.	October H.	November D.	November H.	December D.	December H.
54	1777	20	12 A	20	1 A	19	2M	18	3 A
55	1778	10	9M	9	10 A	8	11M	7	12 A
56	1779	29	7M	28	8 A	27	9M	26	9 A
57	1780	17	3 A	17	4M	15	5 A	15	6M
58	1781	6	12 A	6	1 A	5	2M	4	3 A
59	1782	25	10 A	25	11M	23	12 A	23	0 A
60	1783	15	6M	14	7 A	13	8M	12	9 A
61	1784	3	3 A	3	4M	1	5 A	1 30	6M 6 A
62	1785	22	1 A	22	2M	20	3 A	20	3M
63	1786	11	9 A	11	10M	9	11 A	9	0 A
64	1787	1 30	6M 7 A	30	8M	28	9 A	28	9M
65	1788	19	4M	18	5 A	17	6M	16	7 A
66	1789	8	1 A	8	2M	6	3 A	6	4M
67	1790	29	10M	26	11 A	25	0 A	24	12 A
68	1791	6	7 A	16	8M	14	9 A	14	10M
69	1792	5	4 A	4	5 A	3	6M	2	7 A
70	1793	24	2M	23	3 A	22	4M	21	4 A
71	1791	13	10M	12	11 A	11	0 A	11	1M
72	1795	2	7 A	2 31	8M 9 A	30	10M	29	10 A
73	1796	20	4 A	20	5M	18	6 A	18	7M
74	1797	10	1M	9	2 A	8	3M	7	4 A
75	1798	28	11 A	28	0 A	27	1M	26	1 A
76	1799	18	8M	17	9 A	16	10M	15	11 A
1	1800	6	4 A	6	5M	4	6 A	4	7M

Easter Cycle deficient.

388. The *Cycle of Easter*, also called the *Dionysian Period*, is a revolution of 532 years, found by multiplying the Solar Cycle 28 by the Lunar Cycle 19. If the New Moons did not anticipate upon this Cycle, *Easter-day* would always be the *Sunday* next after the first Full Moon which follows the 21st of *March*. But on account of the above anticipation, § 422. to which no proper regard was had before the late alteration of the *Stile*, the *Ecclesiastic Easter* has several times been a week different from the *true Easter* within this last Century: which inconvenience is now remedied by making the Table which used to find *Easter for ever*, in the Common Prayer Book, of no longer use than the Lunar difference from the *New Stile* will admit of.

Number of Direction.

389. The *earliest Easter possible* is the 22d of *March*, the *latest* the 25th of *April*. Within these limits are 35 days, and the number belonging to each of them is called the *Number of Direction*; because thereby the time of Easter is found for any given year. To find the Number of Direction, according to the *New Stile*, enter Table V. following this Chapter, with the compleat hundreds of any given year at the top, and the years thereof (if any) below a hundred at the left hand; and where the columns meet is the Dominical Letter for the given year. Then enter Table I. with the compleat hundreds of the same year at the left hand, and the years below a hundred at the top; and where the columns meet is the Golden Number for the same year. Lastly, enter Table II. with the Dominical Letter at the left hand and Golden Number at the top; and where the columns meet is the Number of Direction for that year; which number, added to the 21st day of *March*, shews on what day, either of *March* or *April*, *Easter Sunday* falls in that year. Thus the Dominical Letter *New Stile* for the year 1757 is *B* (Table V.) and the Golden Number is 10, (Table I.) by which, in

in Table II. the Number of Direction is found to be 20; which, reckoning from the 21ft of *March*, ends on the 10th of *April, that is, Easter Sunday*, in the year 1757. *N. B.* There are always two Dominical Letters to the Leap-year, the first of which takes place to the 24th of *February*, the last for the following part of the year. To find the true *Easter*.

390. *The first seven letters of the Alphabet* are commonly placed in the annual Almanacks, to shew on what days of the week the days of the months fall throughout the year. And because one of those seven Letters must necessarily stand against *Sunday*, it is printed in a capital form, and called the *Dominical Letter*; the other six being inserted in small characters, to denote the other six days of the week. Now, since a common *Julian Year* contains 365 Days, if this number be divided by 7 (the number of days in a week) there will remain one day. If there had been no remainder, it is plain the year would constantly begin and end on the same day of the week. But since 1 remains, it is as plain that the year must begin and end on the same day of the week; and therefore the next year will begin on the day following. Hence, when *January* begins on *Sunday*, *A* is the Dominical or *Sunday* Letter for that year: then, because the next year begins on *Monday*, the *Sunday* will fall on the seventh day, to which is annexed the seventh Letter *G*, which therefore will be the Dominical Letter for all that year: and as the third year will begin on *Tuesday*, the Sunday will fall on the sixth day; therefore *F* will be the *Sunday* Letter for that year. Whence it is evident, that the *Sunday* Letters will go annually in a retrograde order thus, *G*, *F*, *E*, *D*, *C*, *B*, *A*. And in the course of seven years, if they were all common ones, the same days of the week and Dominical Letters would return to the same days of the months. But because there are 366 days in a Leap-year, if this number be divided by 7, there will remain two days over and above the Dominical Letter.

5 2

52 weeks of which the year confifts. And therefore, if the Leap-year begins on *Sunday*, it will end on *Monday*; and the next year will begin on *Tuefday*, the firft *Sunday* whereof muft fall on the fixth of *January*, to which is annexed the Letter *F*, and not *G*, as in common years: by this means, the Leap-year returning every fourth year, the order of the Dominical Letters is interrupted; and the feries cannot return to its firft ftate till after four times feven, or 28 years; and then the fame days of the months return in order to the fame days of the week as before.

To find the Dominical Letter.

391. *To find the Dominical Letter, for any year either before or after the Chriftian Æra.* In Table III. or IV. for *Old Stile*, or V. for *New Stile*, look for the hundreds of years at the head of the Table, and for the years below a hundred (to make up the given year) at the left hand; and where the columns meet, you have the Dominical Letter for the year defired. Thus, fuppofe the Dominical Letter be required for the year of CHRIST 1758 *New Stile*, I look for 1700 at the head of Table V. and for 58 at the left-hand of the fame Table; and in the angle of meeting, I find *A*, which is the Dominical Letter for that year. If it was wanting for the fame year *Old Stile*, it would be found by Table IV. to be *D*. But *to find the Dominical Letter for any given year before* CHRIST, fubtract one from *that* year, and then proceed in all refpects as juft now taught, to find it by Table III. Thus fuppofe the Dominical Letter be required for the 585th year before the firft year of CHRIST, look for 500 at the head of Table III. and for 84 at the left hand; in the meeting of thefe columns is *FE*, which were the Dominical Letters for that year, and fhews that it was a Leap-year; becaufe Leap-year has always two Dominical Letters.

To find the days of the Months.

392. *To find the day of the month anfwering to any day of the week, or the day of the week anfwering to any day of the month, for any year paft or to come.* Having

Having found the Dominical Letter for the given year, enter Table VI. with the Dominical Letter at the head; and under it, all the days in that column are *Sundays*, in the divisions of the months; the next column to the right hand are *Mondays*; the next, *Tuesdays*; and so on to the last column under *G*; from which go back to the column under *A*, and thence proceed toward the right hand as before. Thus, in the year 1757, the Dominical Letter *New Stile* is *B*, in Table V; then in Table VI. all the days under *B* are *Sundays* in that year, *viz.* the 2d, 9th, 16th, 23d, and 30th of *January* and *October*; the 6th, 13th, 20th, and 27th of *February*, *March*, and *November*: the 3d, 10th, and 17th of *April* and *July*, together with the 31st of *July*; and so on to the foot of the column. Then, of course, all the days under *C* are *Mondays*, namely, the 3d, 10th, *&c.* of *January* and *October*; and so of all the rest in that column. If *the day of the week answering to any day of the month* be required, it is easily had from the same Table by the Letter that stands at the top of the column in which the given day of the month is found. Thus, the Letter that stands over the 28th of May is *A*; and in the year 585 before CHRIST, the Dominical Letters were found to be *FE*, § 391; which being a Leap-year, and *E* taking place from the 24th of *February* to the end of that year, shews by the Table that the 25th of *May* was on a *Sunday*; and therefore the 28th must have been on a *Wednesday*; for when *E* stands for *Sunday*, *F* must stand for *Monday*, *G* for *Tuesday*, &c. Hence, as it is said that the famous Eclipse of the Sun foretold by THALES, by which a peace was brought about between the *Medes* and *Lydians*, happened on the 28th of *May*, in the 585th year before CHRIST, it fell on a *Wednesday*.

393. From the multiplication of the Solar Cycle of 28 years into the Lunar Cycle of 19 years, and the *Roman* Indiction of 15 years, arises the great *Julian* Period.

Julian Period, consisting of 7980 years, which had its beginning 764 years before *Strauchius*'s supposed year of the Creation (for no later could all the three Cycles begin together), and it is not yet completed: and therefore it includes all other Cycles, Periods, and Æras. There is but one year in the whole Period that has the same numbers for the three Cycles of which it is made up: and, therefore, if historians had remarked in their writings the Cycles of each year, there had been no dispute about the time of any action recorded by them.

To find the year of this Period:

394. The *Dionysian* or vulgar Æra of CHRIST's birth was about the end of the year of the *Julian* Period 4713; and consequently the first year of his age, according to that account, was the 4714th year of the said Period. Therefore, if to the current year of CHRIST we add 4713, the sum will be the year of the *Julian* Period. So the year 1757 will be found to be the 6470th year of that period. Or, to find the year of the *Julian* Period answering to any given year before the first year of CHRIST, subtract the number of that given year from 4714, and the remainder will be the year of the *Julian* Period. Thus, the year 585 before the first year of CHRIST (which was the 584th before his birth) was the 4129th year of the said Period. Lastly, to find the Cycles of the Sun, Moon, and Indiction, for any given year of this Period, divide the given year by 28, 19, and 15; the three remainders will be the Cycles sought, and the Quotients the numbers of Cycles run since the beginning of the Period. So in the above 4714th year of the *Julian* Period, the Cycle of the Sun was 10, the Cycle of the Moon 2, and the Cycle of Indiction 4; the Solar Cycle having run through 168 courses, the Lunar 248, and the Indiction 314.

And the Cycles of that year.

The true Æra of CHRIST's Birth.

395. The vulgar Æra of CHRIST's Birth was never settled till the year 527, when *Dionysius Exiguus*, a *Roman* Abbot, fixed it to the end of the 4713th year of the *Julian* Period, which was four

5 years

years too late.—For our SAVIOUR was born before the death of *Herod*, who fought to kill him as foon as he heard of his birth. And according to the teftimony of *Jofephus* (B. xvii. ch. 8.) there was an Eclipfe of the Moon in the time of *Herod*'s laft illnefs; which Eclipfe appears by our Aftronomical Tables to have been in the year of the *Julian* Period 4710, *March* 13th, at 3 hours paft midnight at *Jerufalem*. Now as our Saviour muft have been born fome months before *Herod*'s death, fince in the interval he was carried into *Egypt*, the lateft time in which we can fix the true Æra of his birth is about the end of the 4709th year of the *Julian* Period.

There is a remarkable Prophecy delivered to us in the ninth chapter of the book of *Daniel*, which, from a certain *Epoch*, fixes the time of reftoring the ftate of the *Jews*, and of building the walls of *Jerufalem*, the coming of the MESSIAH, his death, and the deftruction of *Jerufalem*.—But fome parts of this prophecy (*Ver*. 25.) are fo injudicioufly pointed in our *Englifh* tranflation of the *Bible*, that, if they be read according to thofe ftops of pointing, they are quite unintelligible.—But the learned Dr. *Prideaux*, by altering thefe ftops, makes the fenfe very plain: and as he feems to me to have explained the whole of it better than any other author I have read on the fubject, I fhall fet down the whole of the Prophecy according as he has pointed it, to fhew in what manner he has divided it into four different parts.

Ver. 24. *Seventy weeks are determined upon thy People, and upon thy holy City, to finifh the tranfgreffion, and to make an end of Sins, and to make reconciliation for Iniquity, and to bring in everlafting Righteoufnefs, and to feal up the Vifion, and the Prophecy, and to anoint the moft holy*. Ver. 25. *Know therefore and underftand, that from the going forth of the Commandment to reftore and build* Jerufalem *unto the* MESSIAH *the Prince fhall be feven weeks and three-*

 fcore

ſcore and two weeks, the ſtreet ſhall be built again, and the wall even in troublous times. Ver. 26. *And after threeſcore and two weeks ſhall* MESSIAH *be cut off, but not for himſelf, and the people of the Prince that ſhall come, ſhall deſtroy the City and Sanctuary, and the end thereof ſhall be with a flood, and unto the end of the War deſolations are determined.* Ver. 27. *And he ſhall confirm the Covenant with many for one week, and in the midſt* of the week he ſhall cauſe the ſacrifice and the oblation to ceaſe, and for the overſpreading of abominations he ſhall make it deſolate even until the Conſummation, and that determined ſhall be poured upon the deſolate.*

This Commandment was given to *Ezra* by *Artaxerxes Longimanus*, in the ſeventh year of that King's reign (*Ezra*, ch. vii. ver. 11—26.) *Ezra* began the work, which was afterwards accompliſhed by *Nehemiah:* in which they met with great oppoſition and trouble from the *Samaritans* and others, during the firſt ſeven weeks, or 49 years.

From this accompliſhment till the time when CHRIST's meſſenger, *John* the Baptiſt, began to preach the Kingdom of the MESSIAH, 62 weeks, or 434 years.

From thence to the beginning of CHRIST's public miniſtry, half a week, or $3\frac{1}{2}$ years.

And from thence to the death of CHRIST, half a week, or $3\frac{1}{2}$ years; in which half week he preached, and *confirmed the Covenant* of the Goſpel with many.

In all, from the going forth of the Commandment till the Death of CHRIST, 70 weeks, or 490 years.

And, laſtly, in a very ſtriking manner, the Prophecy foretels what ſhould come to paſs after the expiration of the *ſeventy weeks*; namely, *the Deſtruction of the City and Sanctuary by the people of the Prince that was to come*; which were the *Roman*

* The Doctor ſays, that this ought to be rendered, *the half part of the week*, not *the midſt*.

armies, under the command of *Titus* their Prince, who came upon *Jerusalem* as a torrent, with their idolatrous images, which were an abomination to the *Jews*, and under which they marched against them, invaded their land, and besieged their holy City, and by a calamitous war brought such utter destruction upon both, that the *Jews* have never been able to recover themselves, even to this day.

Now, both by the undoubted Canon of *Ptolemy*, and the famous *Æra* of *Nabonassar*, the beginning of the seventh year of the reign of *Artaxerxes Longimanus*, King of *Persia*, (who is called *Ahasuerus* in the book of *Esther*) is pinned down to the 4256th year of the *Julian* Period, in which year he gave *Ezra* the above-mentioned ample Commission: from which count 490 years to the death of CHRIST, and it will carry the same to the 4746th year of the *Julian* Period.

Our *Saturday* is the *Jewish* Sabbath: and it is plain from St. *Mark*, ch. xv. ver. 42. and St. *Luke*, ch. xxiii. ver. 54, that CHRIST was crucified on a *Friday*, seeing the crucifixion was on the day next before the *Jewish* Sabbath.—And according to St. *John*, ch. xviii. ver. 28. on the day that the Passover was to be eaten, at least by many of the *Jews*.

The *Jews* reckoned their months by the Moon, and their years by the apparent revolution of the Sun: and they ate the Passover on the 14th day of the month of *Nisan*, which was the first month of their year reckoning from the first appearance of the New Moon, which at that time of the year might be on the evening of the day next after the change, if the sky was clear. So that their 14th day of the month answers to our fifteenth day of the Moon, on which she is full.—Consequently, the Passover was always kept on the day of Full Moon.

And the Full Moon at which it was kept, was *that* one which happened next after the Vernal Equinox. For *Josephus* expresly says (*Antiq.* B. iii. ch. 10.) "The Passover was kept on the 14th day "of the month of *Nisan*, according to the Moon "when the Sun was in *Aries*."—And the Sun always enters *Aries* at the instant of the Vernal Equinox; which, in our Saviour's time, fell on the 22d day of *March*.

The dispute among Chronologers about the year of Christ's Death is limited to four or five years at most.—But, as we have shewn that he was crucified on the day of a Pascal Full Moon, and on a *Friday*, all that we have to do, in order to ascertain the year of his death, is only to compute in which of those years there was a Passover Full Moon on a *Friday*.—For, the Full Moons anticipate eleven days every year (12 Lunar Months being so much short of a Solar year), and therefore, once in every three years at least, the Jews were obliged to set their Passover a whole month forwarder than it fell by the course of the Moon, on the year next before, in order to keep it at the Full Moon next after the Equinox; therefore there could not be two Passovers on the same nominal day of the week within the compass of a few neighbouring years. And I find by calculation, the *only* Passover Full Moon that fell on a *Friday*, for several years before or after the disputed year of the Crucifixion, was on the 3d day of *April*, in the 4746th year of the *Julian* Period, which was the 490th year after *Ezra* received the above-mentioned Commission from *Artaxerxes Longimanus*, according to *Ptolemy*'s Canon, and the year in which the Messiah was to be cut off, according to the Prophecy, reckoning from the going forth of *that* Commission or Commandment: and this 490th year was the 33d year of our Saviour's Age, reckoning from the vulgar Æra of his birth; but the 37th, reckoning from the true Æra thereof.

And, when we reflect on what the *Jews* told him, some time before his death (*John*, viii. 57.) "*Thou "art not yet fifty years old*," we must confess that it should seem much likelier to have been said to a person

person near forty than to one but just turned of thirty. And we may easily suppose that St. *Luke* expressed himself only in round numbers, when he said that *Christ was baptized about the 30th year of his age*, when he began his public ministry; as our SAVIOUR himself did, when he said he should lie *three days and three nights in the grave.*

The 4746th year of the *Julian* Period, which we have astronomically proved to be the year of the Crucifixion, was the 4th year of the 202d Olympiad; in which year, *Phlegon*, a heathen writer, tells us, *there was the most extraordinary Eclipse of the Sun that ever was seen.* But I find by calculation, that there could be no total Eclipse of the Sun at *Jerusalem*, in a natural way, in that year.—So that what *Phlegon* here calls an Eclipse of the Sun seems to have been the great darkness for three hours at the time of our SAVIOUR's Crucifixion, as mentioned by the Evangelists: a darkness altogether supernatural, as the Moon was then in the side of the Heavens opposite to the Sun: and therefore could not possibly darken the Sun to any part of the Earth.

396. As there are certain fixed points in the Heavens from which Astronomers begin their computations, so there are certain points of time from which historians begin to reckon; and these points, or roots of time, are called *Æras* or *Epochs*. The most remarkable *Æras* are those of the *Creation*, the *Greek Olympiads*, the building of *Rome*, the *Æra* of *Nabonassar*, the death of *Alexander*, the Birth of CHRIST, the *Arabian Hegira*, and the *Persian Yesdegird*: all which, together with several others of less note, have their Beginnings in the following Table fixed to the years of the *Julian Period*, to the Age of the World at those times, and to the Years before and after the year of CHRIST's birth.

A Table of remarkable Æras and Events.

	Julian Period.	Y. of the World.	Before Christ.
1. The Creation of the World — —	706	0	4007
2. The Deluge, or *Noah*'s Flood — —	2362	1656	2351
3. The *Assyrian* Monarchy founded by *Nimrod* —	2537	1831	2176
4. The Birth of *Abraham* — — —	2714	2008	1999
5. The Destruction of *Sodom* and *Gomorrah* —	2816	2110	1897
6. The beginning of the Kingdom of *Athens* by *Cecrops*	3157	2451	1556
7. *Moses* receives the Ten Commandments — —	3222	2516	1491
8. The Entrance of the *Israelites* into *Canaan* —	3262	2556	1451
9. The *Argonautic* Expedition — —	3420	2714	1293
10. The Destruction of *Troy* — — —	3504	2798	1209
11. The Beginning of King *David*'s Reign — —	3650	2944	1063
12. The Foundation of *Solomon*'s Temple — —	3701	2995	1012
13. *Lycurgus* forms his excellent Laws — —	3829	3103	884
14. *Arbaces*, the first King of the *Medes* — —	3838	3132	875
15. *Mandaucus*, the second — — —	3865	3159	848
16. *Sosarmus*, the third — — —	3915	3209	798
17. The Beginning of the *Olympiads* — —	3938	3232	775
18. *Attica*, the fourth King of the *Medes* — —	3945	3239	768
19. The *Catonian Epocha* of the building of *Rome* —	3961	3255	752
20. The Æra of *Nabonassar* — — —	3967	3261	746
21. The Destruction of *Samaria* by *Salmaneser* —	3992	[illegible]	721
22. The first Eclipse of the Moon on Record —	3993	3287	720
23. *Cardicea*, the fifth King of the *Medes* — —	3996	3290	717
24. *Phraortes*, the sixth — — —	4058	3352	655
25. *Cyaxares*, the seventh — — —	4080	3374	633
26. The first *Babylonish* Captivity by *Nebuchadnezzar*	410[illegible]	3401	606
27. The long War ended between the *Medes* and *Lydians*	4111	3405	602
28. The second *Babylonish* Captivity, and Birth of *Cyrus*	4114	3408	599
29. The Destruction of *Solomon*'s Temple — —	4125	3419	588
30. *Nebuchadnezzar* struck with Madness — —	4144	3438	569
31. *Daniel*'s Vision of the four Monarchies — —	4158	3452	555
32. *Cyrus* begins to reign in the *Persian* Empire - -	4177	3471	536
33. The Battle of *Marathon* — —	4223	3517	490
34. *Artaxerxes Longimanus* begins to reign — —	4249	3543	464
35. The Beginning of *Daniel*'s seventy Weeks of Years	4256	3550	457
36. The Beginning of the *Peloponnesian* War — —	428[illegible]	3576	431
37. *Alexander*'s Victory at *Arbela* — —	4383	3677	330
38. His Death — — —	4390	3684	323
39. The Captivity of 100,000 *Jews* by King *Ptolemy* —	4393	3687	320
40. The Colossus of *Rhodes* thrown down by an Earthquake —	4491	3875	222
41. *Antiochus* defeated by *Ptolemy Philopater* — —	4496	3790	217
42. The famous ARCHIMEDES murdered at *Syracuse* —	4506	3800	207
43. *Jason* butchers the Inhabitants of *Jerusalem* —	4543	3837	170
44. *Corinth* plundered and burnt by Consul *Mummius*	4567	3861	146
45. *Julius Cæsar* invades *Britain* — —	4659	3953	54
46. He corrects the Calendar — — —	4677	3961	46
47. Is killed in the Senate-House — —	4671	3965	42

	Julian Period.	Y. of the World.	Before Chrift.
48. *Herod* made King of *Judea* — —	4673	3967	40
49. *Anthony* defeated at the Battle of *Actium* — —	4683	3977	30
50. *Agrippa* builds the *Pantheon* at *Rome* — —	4688	3982	25
51. The true Æra of CHRIST's Birth — —	4709	4003	4
52. The Death of *Herod* — — —	4710	4004	3
			After Chrift.
53. The *Dionyfian* or vulgar Æra of CHRIST's Birth	4713	4007	0
54. The true year of his Crucifixion — —	4746	4040	33
55. The Deftruction of *Jerufalem* — —	4783	4077	70
56. *Adrian* builds the Long Wall in *Britain* — —	4833	4127	120
57. *Conftantius* defeats the *Picts* in *Britain* — —	5019	4313	306
58. The Council of *Nice* — — —	5038	4332	325
59. The Death of *Conftantine the Great* — —	5050	4344	337
60. The *Saxons* invited into *Britain* — —	5158	4452	445
61. The *Arabian Hegira* — — —	5335	4629	622
62. The Death of *Mahommed* the pretended Prophet —	5343	4637	630
63. The *Perfian Yefdegird* — — —	5344	4638	631
64. The Sun, Moon, and all the Planets in *Libra*, *Sept.* 14, as feen from the Earth	5899	5193	1186
65. The Art of Printing difcovered — —	6153	5447	1440
66. The Reformation begun by *Martin Luther* — —	6230	5524	1517

Age of the World uncertain.

In fixing the year of the Creation to the 706th year of the *Julian* Period, which was the 4007th year before the year of CHRIST's Birth, I have followed Mr. *Bedford* in his Scripture Chronology, printed A. D. 1730, and Mr. *Kennedy*, in a work of the fame kind, printed A. D. 1762.—Mr. *Bedford* takes it only for granted that the World was created at the time of the Autumnal Equinox; but Mr. *Kennedy* affirms that the faid Equinox was at the noon of the fourth day of the Creation-week, and that the Moon was then 24 hours paft her Oppofition to the Sun.—If *Mofes* had told us the fame things, we fhould have had fufficient *data* for fixing the *Æra* of the Creation: but, as he has been filent on thefe points, we muft confider the beft accounts of Chronologers as entirely hypothetical and uncertain.

TABLE

TABLE I. *Shewing the Golden Number (which is the same both in the Old and New Stile) from the Christian Æra to* A. D. 380.

Years less than an Hundred.

Hundreds of Years.		0 19 38 57 76 95	1 20 39 58 77 96	2 21 40 59 78 97	3 22 41 60 79 98	4 23 42 61 80 99	5 24 43 62 81	6 25 44 63 82	7 26 45 64 83	8 27 46 65 84	9 28 47 66 85	10 29 48 67 86	11 30 49 68 87	12 31 50 69 88	13 32 51 70 89	14 33 52 71 90	15 34 53 72 91	16 35 54 73 92	17 36 55 74 93	18 37 56 75 94
0	1900	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
100	2000	6	7	8	9	10	11	12	13	14	15	16	17	18	19	1	2	3	4	5
200	2100	11	12	13	14	15	16	17	18	19	1	2	3	4	5	6	7	8	9	10
300	2200	16	17	18	19	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
400	2300	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	1
500	2400	7	8	9	10	11	12	13	14	15	16	17	18	19	1	2	3	4	5	6
600	2500	12	13	14	15	16	17	18	19	1	2	3	4	5	6	7	8	9	10	11
700	2600	17	18	19	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
800	2700	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	1	2
900	2800	8	9	10	11	12	13	14	15	16	17	18	19	1	2	3	4	5	6	7
1000	2900	13	14	15	16	17	18	19	1	2	3	4	5	6	7	8	9	10	11	12
1100	3000	18	19	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1200	3100	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	1	2	3
1300	3200	9	10	11	12	13	14	15	16	17	18	19	1	2	3	4	5	6	7	8
1400	3300	14	15	16	17	18	19	1	2	3	4	5	6	7	8	9	10	11	12	13
1500	3400	19	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1600	3500	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	1	2	3	4
1700	3600	10	11	12	13	14	15	16	17	18	19	1	2	3	4	5	6	7	8	9
1800	3700	15	16	17	18	19	1	2	3	4	5	6	7	8	9	10	11	12	13	14

Table II. *Shewing the Number of Direction, for finding Easter Sunday by the Golden Number and Dominical Letter.*

G. N.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
A	26	19	5	26	12	33	19	12	26	19	5	26	12	5	26	12	33	19	12
B	27	13	6	27	13	34	20	13	27	20	6	27	13	6	20	13	34	20	6
C	28	14	7	21	14	35	21	7	28	21	7	28	14	7	21	14	28	21	7
D	29	15	8	22	15	29	22	8	29	15	8	29	15	1	22	15	29	22	8
E	30	16	2	23	16	30	23	9	30	16	9	23	16	2	23	9	30	23	9
F	24	17	3	24	10	31	24	10	31	17	10	24	17	3	24	10	31	17	10
G	25	18	4	25	11	32	18	11	32	18	4	25	18	4	25	11	32	18	11

This Table is adapted to the New Stile.

TABLE III. *Shewing the Dominical Letters, Old Stile, for 4200 Years before the Christian Æra.*

Bef. Christ.				Hundreds of Years.						
Years less than an Hundred.				0 700 1400 2100 2800 3500	100 800 1500 2200 2900 3600	200 900 1600 2300 3000 3700	300 1000 1700 2400 3100 3800	400 1100 1800 2500 3200 3900	500 1200 1900 2600 3300 4000	600 1300 2000 2700 3400 4100
0	28	56	84	D C	C B	B A	A G	G F	F E	E D
1	29	57	85	E	D	C	B	A	G	F
2	30	58	86	F	E	D	C	B	A	G
3	31	59	87	G	F	E	D	C	B	A
4	32	60	88	B A	A G	G F	F E	E D	D C	C B
5	33	61	89	C	B	A	G	F	E	D
6	34	62	90	D	C	B	A	G	F	E
7	35	63	91	E	D	C	B	A	G	F
8	36	64	92	G F	F E	E D	D C	C B	B A	A G
9	37	65	93	A	G	F	E	D	C	B
10	38	66	94	B	A	G	F	E	D	C
11	39	67	95	C	B	A	G	F	E	D
12	40	68	96	E D	D C	C B	B A	A G	G F	F E
13	41	69	97	F	E	D	C	B	A	G
14	42	70	98	G	F	E	D	C	B	A
15	43	71	99	A	G	F	E	D	C	B
16	44	72		C B	B A	A G	G F	F E	E D	D C
17	45	73		D	C	B	A	G	F	E
18	46	74		E	D	C	B	A	G	F
19	47	75		F	E	D	C	B	A	G
20	48	76		A G	G F	F E	E D	D C	C B	B A
21	49	77		B	A	G	F	E	D	C
22	50	78		C	B	A	G	F	E	D
23	51	79		D	C	B	A	G	F	E
24	52	80		F E	E D	D C	C B	B A	A G	G F
25	53	81		G	F	E	D	C	B	A
26	54	82		A	G	F	E	D	C	B
27	55	83		B	A	G	F	E	D	C

TABLE IV. *Shewing the Dominical Letters, Old Stile, for* 4200 *Years after the Christian Æra.*

After Chr.				Hundreds of Years.						
Years less than an Hundred.				0 700 1400 2100 2800 3500	100 800 1500 2200 2900 3600	200 900 1600 2300 3000 3700	300 1000 1700 2400 3100 3800	400 1100 1800 2500 3200 3900	500 1200 1900 2600 3300 4000	600 1300 2000 2700 3400 4100
0	28	56	84	D C	E D	F E	G F	A G	B A	C B
1	29	57	85	B	C	D	E	F	G	A
2	30	58	86	A	B	C	D	E	F	G
3	31	59	87	G	A	B	C	D	E	F
4	32	60	88	F E	G F	A G	B A	C B	D C	E D
5	33	61	89	D	E	F	G	A	B	C
6	34	62	90	C	D	E	F	G	A	B
7	35	63	91	B	C	D	E	F	G	A
8	36	64	92	A G	B A	C B	C D	E D	F E	G F
9	37	65	93	F	G	A	B	C	D	E
10	38	66	94	E	F	G	A	B	C	D
11	39	67	95	D	E	F	G	A	B	C
12	40	68	96	C B	D C	E D	F E	G F	A G	B A
13	41	69	97	A	B	C	D	E	F	G
14	42	70	98	G	A	B	C	D	E	F
15	43	71	99	F	G	A	B	C	D	E
16	44	72		E D	F E	G F	A G	B A	C B	D C
17	45	73		C	D	E	F	G	A	B
18	46	74		B	C	D	E	F	G	A
19	47	75		A	B	C	D	E	F	G
20	48	76		G F	A G	B A	C B	D C	E D	F E
21	49	77		E	F	G	A	B	C	D
22	50	78		D	E	F	G	A	B	C
23	51	79		C	D	E	F	G	A	B
24	52	80		B A	C B	D C	E D	F E	G F	A G
25	53	81		G	A	B	C	D	E	F
26	54	82		F	G	A	B	C	D	E
27	55	83		E	F	G	A	B	C	D

TABLE V. *The Dominical Letter, New Stile, for 4000 Years after the Christian Æra.*

After Chr.				Hundreds of Years.			
Years lefs than an Hundred.				100 500 900 1300 1700 2100 2500 2900 3300 3700	200 600 1000 1400 1800 2200 2600 3000 3400 3800	300 700 1100 1500 1900 2300 2700 3100 3500 3900	400 800 1200 1600 2000 2400 2800 3200 3600 4000
				C	E	G	B A
1	29	57	85	B	D	F	G
2	30	58	86	A	C	E	F
3	31	59	87	G	B	D	E
4	32	60	88	F E	A G	C B	D C
5	33	61	89	D	F	A	B
6	34	62	90	C	E	G	A
7	35	63	91	B	D	F	G
8	36	64	92	A G	C B	E D	F E
9	37	65	93	F	A	C	D
10	38	65	94	E	G	B	C
11	39	67	95	D	F	A	B
12	40	68	96	C B	E D	G F	A G
13	41	69	97	A	C	E	F
14	42	70	98	G	B	D	E
15	43	71	99	F	A	C	D
16	44	72		E D	G F	B A	C B
17	45	73		C	E	G	A
18	46	74		B	D	F	G
19	47	75		A	C	E	F
20	48	76		G F	B A	D C	E D
21	49	77		E	G	B	C
22	50	78		D	F	A	B
23	51	79		C	E	G	A
24	52	80		B A	D C	F E	G F
25	53	81		G	B	D	E
26	54	82		F	A	C	D
27	55	83		E	G	B	C
28	56	84		D C	F E	A G	B A

TABLE VI. *Shewing the Days of the Months, for both Stiles, by the Dominical Letters.*

Week Days.	A	B	C	D	E	F	G
January 31 October 31	1 8 15 22 29	2 9 16 23 30	3 10 17 24 31	4 11 18 25	5 12 19 26	6 13 20 27	7 14 21 28
Feb. 28-29 March 31 November 30	5 12 19 26	6 13 20 27	7 14 21 28	1 8 15 22 29	2 9 16 23 30	3 10 17 24 31	4 11 18 25
April 30 July 31	2 9 16 23 30	3 10 17 24 31	4 11 18 25	5 12 19 26	6 13 20 27	7 14 21 28	1 8 15 22 29
August 31	6 13 20 27	7 14 21 28	1 8 15 22 29	2 9 16 23 30	3 10 17 24 31	4 11 18 25	5 12 19 26
September 30 December 31	3 10 17 24 31	4 11 18 25	5 12 19 26	6 13 20 27	7 14 21 28	1 8 15 22 29	2 9 16 23 30
May 31	7 14 21 28	1 8 15 22 29	2 9 16 23 30	3 10 17 24 31	4 11 18 25	5 12 19 26	6 13 20 27
June 30	4 11 18 25	5 12 19 26	6 13 20 27	7 14 21 28	1 8 15 22 29	2 9 16 23 30	3 10 17 24

CHAP. XXII.

A Description of the Astronomical Machinery serving to explain and illustrate the foregoing part of this Treatise.

Fronting the Title-page. The ORRERY.

397. THE ORRERY. This Machine shews the Motions of the Sun, Mercury, Venus, Earth, and Moon, and occasionally, the superior Planets, Mars, Jupiter, and Saturn, may be put on; Jupiter's four Satellites are moved round him in their proper times by a small winch; and Saturn has his five Satellites, and his Ring, which keeps its Parallelism round the Sun; and by a Lamp put in the Sun's place, the Ring shews all the Phases described in the 204th Article.

The Sun.

In the Center, No. 1, represents the SUN, supported by its Axis inclining almost 8 Degrees from the Axis of the Ecliptic; and turning round in $25\frac{1}{4}$ days on its Axis, of which the North Pole inclines toward the 8th Degree of Pisces in the great Ecliptic (No. 11.), whereon the months and Days are engraven over the Signs and Degrees in which the Sun appears, as seen from the Earth, on the different days of the year.

The Ecliptic.

Mercury.

The nearest Planet (No. 2.) to the Sun is *Mercury*, which goes round him in 87 days 23 hours, or $87\frac{23}{24}$ diurnal rotations of the Earth; but has no Motion round its Axis in the Machine, because the time of its diurnal Motion in the Heavens is not known to us.

Venus.

The next Planet in order is *Venus* (No. 3.) which performs her annual course in 224 days 17 hours; and turns round her Axis in 24 days 8 hours, or in $24\frac{1}{3}$ diurnal rotations of the Earth. Her Axis inclines 75 Degrees from the Axis of the Ecliptic, and her North Pole inclines toward the 20th Degree of Aquarius, according to the observations of

Bianchini.

Bianchini. She ſhews all the Phenomena deſcribed from the 30th to the 44th Article in Chap. I.

Next without the Orbit of Venus is the *Earth,* (No. 4.) which turns round its Axis, to any fixed point at a great diſtance, in 23 hours 56 minutes 4 ſeconds, of mean ſolar time (§ 221, *& ſeq.*) but from the Sun to the Sun again in 24 hours of the ſame time. No. 6. is a ſydereal Dial-plate under the Earth; and No. 7. a ſolar Dial-plate on the cover of the Machine. The Index of the former ſhews ſydereal, and of the latter, ſolar time; and hence, the former Index gains one entire revolution on the latter every year, as 365 ſolar or natural days contain 366 ſydereal days, or apparent revolutions of the Stars. In the time that the Earth makes 365¼ diurnal rotations on its Axis, it goes once round the Sun in the Plane of the Ecliptic; and always keeps oppoſite to a moving Index (No. 10.) which ſhews the Sun's apparent daily change of place, aud alſo the days of the months. The Earth.

The Earth is half covered with a black cap, for dividing the apparently enlightened half next the Sun from the other half, which when turned away from him is in the dark. The edge of the cap repreſents *the Circle bounding Light and Darkneſs,* and ſhews at what time the Sun riſes and ſets to all places throughout the year. The Earth's Axis inclines 23½ Degrees from the Axis of the Ecliptic, the North Pole inclines toward the beginning of Cancer, and keeps its Paralleliſm throughout its annual Courſe, § 48, 202; ſo that in Summer the northern parts of the Earth incline toward the Sun, and in Winter from him; by which means the different lengths of days and nights, and the cauſe of the various ſeaſons, are demonſtrated to ſight.

There is a broad Horizon, to the upper ſide of which is fixed a Meridian ſemicircle in the North and South Points, graduated on both ſides from the Horizon to 90° in the Zenith, or vertical Point.

The edge of the Horizon is graduated from the Eaſt and Weſt to the South and North Points, and within theſe Diviſions are the Points of the Compaſs. From the lower ſide of this thin Horizon-plate ſtand out four ſmall Wires, to which is fixed a Twilight-circle, 18 Degrees from the graduated ſide of the Horizon all round. This Horizon may be put upon the Earth (when the cap is taken away) and rectified to the Latitude of any place: and then, by a ſmall Wire called *the Solar Ray*, which may be put on ſo as to proceed directly from the Sun's Center toward the Earth's, but to come no farther than almoſt to touch the Horizon. The beginning of Twilight, time of Sun-riſing, with his Amplitude, Meridian Altitude, Time of Setting, Amplitude then, and End of Twilight, are ſhewn for every day of the year, at *that* place to which the Horizon is rectified.

The Moon. The Moon (No. 5.) goes round the Earth, from between it and any fixed point at a great diſtance, in 27 days 7 hours 43 minutes, or through all the Signs and Degrees of her Orbit; which is called *her Periodical Revolution*; but ſhe goes round from the Sun to the Sun again, or from Change to Change, in 29 days 12 hours 45 minutes, which is *her Synodical Revolution*; and in that time ſhe exhibits all the Phaſes already deſcribed, § 255.

When the above-mentioned Horizon is rectified to the Latitude of any given place, the Times of the Moon's riſing and ſetting, together with her Amplitude, are ſhewn to that place as well as the Sun's; and all the various Phenomena of the Harveſt-Moon, § 273, *& ſeq.* are made obvious to ſight.

The Nodes. The Moon's orbit (No. 9.) is inclined to the Ecliptic (No. 11.), one half being above, and the other below it. The Nodes or Points at o and o, lie in the Plane of the Ecliptic, as deſcribed § 317, 318, and ſhift backward through all its Signs and Degrees in 18⅔ years. The Degrees of the Moon's

6 Latitude,

Latitude, to the higheſt at *NL* (North Latitude) and loweſt at *SL* (South Latitude), are engraven both ways from her Nodes at o and o; and, as the Moon riſes and falls in her Orbit according to its inclination, her Latitude and Diſtance from her Nodes are ſhewn for every day; having firſt rectified her Orbit ſo as to ſet the Nodes to their proper places in the Ecliptic: and then, as they come about at different, and almoſt oppoſite, times of the year, § 319, and point twice toward the Sun, all the Eclipſes may be ſhewn for hundreds of years (without any new rectification) by turning the Machinery backward for time paſt, or forward for time to come. At 17 Degrees diſtance from each Node, on both ſides is engraven a ſmall Sun; and at 12 Degrees diſtance, a ſmall Moon; which ſhew the limits of ſolar and lunar Eclipſes, § 317: and when, at any change, the Moon falls between either of theſe Suns and the Node, the Sun will be eclipſed on the day pointed to by the Annual Index (No. 10.); and as the Moon has then North or South Latitude, one may eaſily judge whether that Eclipſe will be viſible in the Northern or Southern Hemiſphere; eſpecially as the Earth's Axis inclines toward the Sun or from him at that time. And when, at any Full, the Moon falls between either of the little Moons and Node, ſhe will be eclipſed, and the Annual-Index ſhews the day of that Eclipſe. There is a Circle of $29\frac{1}{2}$ equal parts (No. 8.) on the cover of the Machine, on which an Index ſhews the days of the Moon's age.

A ſemi-ellipſis and ſemi-circle are fixed to an elliptical ring, which being put like a cap upon the Earth, and the forked part *F* upon the Moon, ſhews the tides as the Earth turns round within them, and they are led round it by the Moon. When the different places come to the ſemi-ellipſis *A a E b B*, they have Tides of Flood; and when they come to the ſemi-circle *CED*, they have Tides of Ebb, § 304, 305; the Index on the Hour- PLATE IX. Fig. X.

 Circle

Circle (No. 7.) ſhewing the times of theſe Phenomena.

There is a jointed Wire, of which one end being put into a hole in the upright ſtem that holds the Earth's cap, and the Wire laid into a ſmall forked piece which may be occaſionally put upon Venus or Mercury, ſhews the direct and retrograde Motions of theſe two Planets, with their ſtationary Times and Places as ſeen from the Earth.

The whole Machinery is turned by a winch or handle (No. 12.), and is ſo eaſily moved, that a clock may turn it without any danger of ſtopping.

To give a Plate of the wheel-work of this Machine would anſwer no purpoſe, becauſe many of the wheels lie ſo behind others, as to hide them from ſight in any view whatever.

Another Orrery.

Plate VI. Fig. I.

398. *Another* Orrery. In this Machine, which is the ſimpleſt I ever ſaw, for ſhewing the diurnal and annual motions of the Earth, together with the motion of the Moon and her Nodes, *A* and *B* are two oblong ſquare plates held together by four upright pillars; of which three appear at *f*, *g*, and *g* 2. Under the Plate *A* is an endleſs ſcrew on the Axis of the handle *h*, which works in a wheel fixed on the ſame Axis with the double-grooved wheel *E*; and on the top of this Axis is fixed the toothed wheel *i*, which turns the pinion *k*, on the top of whoſe Axis is the pinion *k* 2 which turns another pinion *b* 2, and that turns a third, which being fixed on *a* 2, the Axis of the Earth *U*, turns it round, and the Earth with it: this laſt Axis inclines in an angle of 23½ Degrees. The ſupporter *X* 2, in which the Axis of the Earth turns, is fixed to the moveable Plate *C*.

In the fixed Plate *B*, beyond *H*, is fixed the ſtrong wire *d*, on which hangs the Sun *T*, ſo as it may turn round the wire. To this Sun is fixed the wire or ſolar ray *Z*, which (as the Earth *U* turns round its Axis) points to all the places that the Sun paſſes vertically over, every day of the year.

The

The Earth is half covered with a black cap *a*, as in the former Orrery, for dividing the day from the night; and, as the different places come out from below the edge of the cap, or go in below it, they ſhew the times of Sun-riſing and ſetting every day of the year. This cap is fixed on the wire *b*, which has a forked piece *C* turning round the wire *d*: and, as the Earth goes round the Sun it carries the Cap, Wire, and ſolar Ray round him; ſo that the ſolar Ray conſtantly points toward the Earth's Center.

On the Axis of the pinion *k* is the pinion *m*, which turns a wheel on the cock or ſupporter *n*, and on the Axis of this wheel neareſt *n* is a pinion (hid from view) under the plate *C*, which pinion turns a wheel that carries the Moon *V* round the Earth *U*; the Moon's Axis riſing and falling in the ſocket W, which is fixed to the triangular piece above *Z*; and this piece is fixed to the top of the Axis of the laſt-mentioned wheel. The ſocket *W* is ſlit on the outermoſt ſide; and in this ſlit the two pins near *Y*, fixed in the Moon's Axis, move up and down; one of them being above the inclined Plane *YX*; and the other below it. By this mechaniſm, the Moon *V* moves round the Earth *T* in the inclined Orbit *q*, parallel to the Plane of the Ring *YX*; of which the Deſcending Node is at *X*, and the Aſcending Node oppoſite to it, but hid by the ſupporter *X* 2.

The ſmall wheel *E* turns the large wheels *D* and *F*, of equal diameters, by cat-gut ſtrings croſſing between them: and the Axes of theſe two wheels are cranked at *G* and *H*, above the Plate *B*. The upright ſtems of theſe cranks going through the Plate *C*, carry it over and over the fixed Plate *B*, with a motion which carries the Earth *U* round the Sun *T*, keeping the Earth's Axis always parallel to itſelf, or ſtill inclining toward the left hand of the plate; and ſhewing the viciſſitudes of ſeaſons, as deſcribed in the tenth chapter. As the Earth

 goes

goes round the Sun, the pinion *k* goes round the wheel *i*, for the Axis of *k* never touches the fixed Plate *B*, but turns on a wire fixed into the Plate *C*.

On the top of the crank *G* is an Index *L*, which goes round the Circle *m* 2 in the time that the Earth goes round the Sun, and points to the days of the months; which together with the names of the ſeaſons, are marked in this Circle.

This Index has a ſmall grooved wheel *L* fixed upon it, round which, and the Plate *Z*, goes a cat-gut ſtring croſſing between them; and by this means the Moon's inclined Plane *Y X*, with its Nodes, is turned backward, for ſhewing the times and returns of Eclipſes, § 310. 320.

The following parts of this machine muſt be conſidered as diſtinct from thoſe already deſcribed.

Toward the right hand, let *S* be the Earth hung on the wire *e*, which is fixed into the Plate *B*; and let *O* be the Moon fixed on the Axis *M*, and turning round within the cap *P*, in which, and in the Plate *C*, the crooked wire *Q* is fixed. On the Axis *M* is alſo fixed the Index *K*, which goes round a Circle *b* 2, divided into 29½ equal parts, which are the days of the Moon's age: but to avoid confuſion in the ſcheme, it is only marked with the numeral figures 1 2 3 4, for the Quarters. As the crank *H* carries this Moon round the Earth *S* in the Orbit *t*, ſhe ſhews all her Phaſes by means of the cap *P* for the different days of her age, which are ſhewn by the Index *K*; this Index turning juſt as the Moon *O* does, demonſtrates her turning round her Axis, as ſhe ſtill keeps the ſame ſide toward the Earth *S*, § 262.

At the other end of the Plate *C*, a Moon *N* goes round an Earth *R* in the Orbit *p*. But this Moon's Axis is ſtuck faſt into the Plate *C* at *S* 2, ſo that neither Moon nor Axis can turn round; and as this Moon goes round her Earth, ſhe ſhews herſelf all round to it; which proves, that if the Moon

was

was ſeen all round from the Earth in a Lunation, ſhe could not turn round her Axis.

N. B. If there were only the two Wheels *D* and *F*, with a cat-gut ſtring over them, but not croſſing between them, the Axis of the Earth *U* would keep its Parallelifm round the Sun *T*, and ſhew all the ſeaſons; as I ſometimes make theſe Machines; and the Moon *O* would go round the Earth *S*, ſhewing her Phaſes as above; as likewiſe would the Moon *N* round the Earth *R*; but then, neither could the diurnal motion of the Earth *U* on its Axis be ſhewn, nor the Motion of the Moon *V* round the Earth.

399. In the year 1746 I contrived a very ſimple Machine, and deſcribed its performance in a ſmall Treatiſe upon the Phenomena of the Harveſt-Moon, publiſhed in the year 1747. I improved it ſoon after, by adding another wheel, and called it *The Calculator*. It may be eaſily made by any Gentleman who has a mechanical Genius. The CALCULATOR.

The great flat Ring ſupported by twelve pillars, and on which the twelve Signs with their reſpective Degrees are laid down, is the Ecliptic; nearly in the center of it is the Sun *S*, ſupported by the ſtrong crooked Wire *I*; and from the Sun proceeds a Wire *W*, called the *Solar Ray*, pointing toward the center of the Earth *E*, which is furniſhed with a moveable Horizon *H*, together with a brazen Meridian, and Quadrant of Altitude. *R* is a ſmall Ecliptic, whoſe Plane coincides with that of the great one, and has the like Signs and Degrees marked upon it; and is ſupported by two Wires *D* and *D*, which are put into the Plate *PP*, but may be taken off at pleaſure. As the Earth goes round the Sun, the Signs of this ſmall Circle keep parallel to themſelves, and to thoſe of the great Ecliptic. When it is taken off, and the ſolar Ray *W*, drawn farther out, ſo as almoſt to touch the Horizon *H*, or the Quadrant of Altitude, the Horizon PLATE VIII. Fig. I.

 being

being rectified to any given Latitude, and the Earth turned round its Axis by hand, the point of the Wire *W* fhews the Sun's Declination in paffing over the graduated brafs Meridian, and his height at any given time upon the Quadrant of Altitude, together with his Azimuth, or point of bearing upon the Horizon at that time; and likewife his Amplitude, and time of rifing and fetting by the Hour-Index, for any day of the year that the Annual-Index *U* points to in the Circle of Months below the Sun. *M* is a Solar-Index or Pointer fupported by the wire *L*, which is fixed into the knob *K*: the ufe of this Index is to fhew the Sun's place in the Ecliptic every day in the year; for it goes over the Signs and Degrees as the Index *U* goes over the Months and Days; or rather, as they pafs under the Index *U*, in moving the cover-plate with the Earth and its Furniture round the Sun; for the Index *U* is fixed tight on the immoveable Axis in the Center of the Machine. *K* is a knob or handle for moving the Earth round the Sun, and the Moon round the Earth.

As the Earth is carried round the Sun, its Axis conftantly keeps the fame oblique direction, or parallel to itfelf, § 48, 202, fhewing thereby the different lengths of days and nights at different times of the year, with all the various feafons. And, in one annual revolution of the Earth, the Moon *M* goes $12\frac{1}{3}$ times round it from Change to Change, having an occafional provifion for fhewing her different Phafes. The lower end of the Moon's Axis bears by a fmall friction-wheel upon the inclined Plane *T*, which caufes the Moon to rife above and fink below the Ecliptic *R* in every Lunation; croffing it in her Nodes, which fhift backward through all the Signs and Degrees of the faid Ecliptic, by the retrograde motion of the inclined Plane *T*, in 18 years and 225 days. On this Plane the Degrees and Parts of the Moon's North and South Latitude are laid down from both the

the Nodes, one of which, viz. the Defcending Node, appears at o, by *D N* above *B*; the other Node being hid from Sight on this Plane by the Plate *P P*; and from both Nodes, at proper diftances, as in the other Orrery, the limits of Eclipfes are marked, and all the folar and lunar Eclipfes are fhewn in the fame manner, for any given year within the limits of 6000, either before or after the Chriftian Æra. On the plate that covers the wheel-work, under the Sun *S*, and round the knob *K*, are Aftronomical Tables, by which the Machine may be rectified to the beginning of any given year within thefe limits, in three or four minutes of time; and when once fet right, may be turned backward for 300 years paft, or forward for as many to come, without requiring any new rectification. There is a method for its adding up the 29th of *February* every fourth year, and allowing only 28 days to that month for every other three; but all this being performed by a particular manner of cutting the teeth of the Wheels, and dividing the Month-Circle, too long and intricate to be defcribed here, I fhall only fhew how thefe motions may be performed near enough for common ufe, by wheels with grooves and cat-gut ftrings round them; only here I muft put the Operator in mind, that the grooves are to be made fharp (not round) bottomed, to keep the ftrings from flipping.

The Moon's Axis moves up and down in the focket *N* fixed into the bar *O* (which carries her round the Earth) as fhe rifes above or finks below the Ecliptic; and immediately below the inclined Plane *T* is a flat circular plate (between *Y* and *T*) on which the different Eccentricities of the Moon's Orbit are laid down: and likewife her mean Anomaly and elliptic Equation, by which her true Place may be very nearly found at any time. Below this Apogee-plate, which fhews the Anomaly, &c. is a Circle *Y* divided into 29½ equal parts, which

which are the days of the Moon's age: and the forked end *A* of the Index *A B* (Fig. II.) may be put into the Apogee-part of this plate; there being juſt ſuch another index to put into the inclined Plane *T* at the Aſcending Node: and then the curved points *B* of theſe Indexes ſhew the direct Motion of the Apogee, and retrograde Motion of the Nodes through the Ecliptic *R*, with their Places in it at any given time. As the Moon *M* goes round the Earth *E*, ſhe ſhews her Place every day in the Ecliptic *R*, and the lower end of her Axis ſhews her Latitude and Diſtance from her Node on the inclined Plane *T*, alſo her Diſtance from her Apogee and Perigee, together with her mean Anomaly, the then Eccentricity of her Orbit, and her elliptic Equation, all on the Apogee-plate, and the Day of her Age in the Circle *Y* of $29\frac{1}{2}$ equal parts; for every day of the year pointed out by the Annual Index *U* in the Circle of Months.

Having rectified the Machine by the Tables for the beginning of any year, move the Earth and Moon forward by the Knob *K*, until the Annual Index comes to any given day of the month, then ſtop, and not only all the above Phenomena may be ſhewn for that day, but alſo, by turning the Earth round its Axis, the Declination, Azimuth, Amplitude, Altitude of the Moon at any hour, and the Times of her riſing and ſetting, are ſhewn by the Horizon, Quadrant of Altitude, and Hour-Index. And in moving the Earth round the Sun, the days of all the New and Full Moons and Eclipſes in any given year are ſhewn. The Phenomena of the Harveſt-Moon, and thoſe of the Tides, by ſuch a cap as that in Plate IX. Fig. 10. put upon the Earth and Moon, together with the ſolution of many problems not here related, are made conſpicuous.

The eaſieſt, though not the beſt way, that I can inſtruct any mechanical perſon to make the wheel-work

work of ſuch a machine, is as follows: which is the way that I made it, before I thought of numbers exact enough to make it worth the trouble of cutting teeth in the wheels.

Fig. 3d of Plate VIII. is a ſection of this Machine, in which *ABCD* is a frame of wood held together by four pillars at the corners; two of which appear at *AC* and *BD*. In the lower Plate *CD* of this frame are three ſmall friction-wheels, at equal diſtances from each other; two of them appearing at *e* and *e*. As the frame is moved round, theſe wheels run upon the fixed bottom Plate *E E*, which ſupports the whole work. PLATE VIII. Fig. III.

In the center of this laſt-mentioned Plate is fixed the upright Axis *GFFf*, and on the ſame Axis is fixed the Wheel *HHH*, in which are four Grooves, *I*, *X*, *k*, *L*, of different diameters. In theſe Grooves are cat-gut ſtrings going alſo round the ſeparate Wheels *M*, *N*, *O*, and *P*.

The Wheel *M* is fixed on a ſolid Spindle or Axis the lower pivot of which turns at *R* in the under Plate of the moveable frame *AB CD*; and on the upper end of this Axis is fixed the Plate *o o* (which is *P P*, under the Earth, in Fig. 1.), and to this Plate is fixed, at an Angle of 23½ Degrees inclination; the Dial-plate below the Earth *T*; on the Axis of which, the Index *q* is turned round by the Earth. This Axis, together with the Wheel *M*, and Plate *o o*, keep their Paralleliſm in going round the Sun *S*.

On the Axis of the Wheel *M* is a moveable ſocket, on which the ſmall wheel *N* is fixed, and on the upper end of this ſocket is put on tight (but ſo as it may be occaſionally turned by hand) the bar *ZZ* (viz. the bar *O* in Fig. 1.) which carries the Moon *m* round the Earth *T*, by the ſocket *n*, fixed into the bar. As the Moon goes round the Earth, her Axis riſes and falls in the ſocket *n*; becauſe, on the lower end of her Axis, which is turned inward, there is a ſmall friction Wheel *s* running on on the inclined Plane *X* (which is *T* in Fig. 1.) and ſo cauſes the Moon alternately to riſe above and ſink below the little Ecliptic *VV* (*R* in Fig. 1.) in every Lunation.

On the ſocket or hollow axis of the Wheel *N*, there is another ſocket, on which the Wheel *O* is fixed; and the Moon's inclined Plane *X* is put tightly on the upper end of this ſocket, not on a ſquare, but on a round, that it may be occaſionally ſet by hand without wrenching the Wheel or Axle.

Laſtly, on the hollow Axis of the Wheel *O* is another ſocket, on which is fixed the Wheel *P*, and on the upper end of this ſocket is put on tightly the Apogee-plate *Y* (*that* immediately below *T* in Fig. 1.). All theſe Axles turn in the upper Plate of the moveable frame at *Q*; which Plate is covered with the thin Plate *c c* (ſcrewed to it) whereon are the fore-mentioned Tables and Month-Circle in Fig. 1.

The middle part of the thick fixed Wheel *HHH* is much broader than the reſt of it, and comes out between the Wheels *M* and *O* almoſt to the Wheel *N*. To adjuſt the diameters of the Grooves of this fixed Wheel to the Grooves of the ſeparate Wheels *M*, *N*, *O*, and *P*, ſo as they may perform their motions in the proper times, the following method muſt be obſerved.

The Groove of the Wheel *M*, which keeps the Parallelifm of the Earth's Axis, muſt be preciſely of the ſame Diameter as the lower Groove *I* of the fixed Wheel *HHH*; but, when this Groove is ſo well adjuſted as to ſhew, that in ever ſo many annual revolutions of the Earth, its Axis keeps its Parallelifm, as may be obſerved by the ſolar Ray *W* (Fig. 1.) always coming preciſely to the ſame Degree of the ſmall Ecliptic *R* at the end of every annual revolution, when the Index *M* points to the like Degree in the great Ecliptic; then, with the edge of a thin File, give the Groove of the Wheel *M* a ſmall rub all round, and, by that means leſ-

ſening

fening the Diameter of the Grove perhaps about the 20th part of a hair's breadth, it will caufe the Earth to fhew the preceffion of the Equinoxes; which, in many annual revolutions, will begin to be fenfible, as the Earth's Axis deviates flowly from its Parallelifm, § 246, toward the antecedent Signs of the Ecliptic.

The Diameter of the Groove of the Wheel *N*, which carries the Moon round the Earth, muft be to the Diameter of the Groove *X*, as a Lunation is to a year, that is, as $29\frac{1}{2}$ to $365\frac{1}{4}$.

The Diameter of the Groove of the Wheel *O*, which turns the inclined Plane *X* with the Moon's Nodes backward, muft be to the Diameter of the Groove *k*, as 20 to $18\frac{225}{365}$. And,

Laftly, the Diameter of the Groove of the Wheel *P*, which carries the Moon's Apogee forward, muft be to the Diameter of the Groove *L*, as 70 to 62.

But after all this nice adjuftment of the Grooves to the proportional times of their refpective Wheels turning round; and which feems to promife very well in Theory, there will ftill be found a neceffity of a farther adjuftment by hand; becaufe proper allowance muft be made for the Diameters of the cat-gut ftrings: and the Grooves muft be fo adjufted by hand, as, that in the time the Earth is moved once round the Sun, the Moon muft perform 12 fynodical revolutions round the Earth, and be almoft 11 days old in her 13th revolution. The inclined Plane with its Nodes muft go once round backward through all the Signs and Degrees of the fmall Ecliptic in 18 annual revolutions of the Earth, and 225 days over. And the Apogee-plate muft go once round forward, fo as its Index may go over all the Signs and Degrees of the fmall Ecliptic in eight years (or fo many annual revolutions of the Earth) and 312 days over.

N. B. The ftring which goes round the Grooves *X* and *N* for the Moon's Motion muft crofs between thefe wheels; but all the reft of the ftrings

go

go in their respective Grooves, *I M*, *k O*, and *L P*, without crossing.

The COMETARIUM.

400. The COMETARIUM. This curious Machine shews the Motion of a Comet, or eccentric Body, moving round the Sun, describing equal areas in equal times, § 152, and may be so contrived as to shew such a Motion for any Degree of Eccentricity. It was invented by the late Dr. DESAGULIERS.

PLATE IV. Fig. IV.

The dark elliptical Groove round the letters *abcdefghiklm* is the Orbit of the Comet *Y*: this Comet is carried round in the Groove, according to the order of letters, by the Wire *W* fixed in the Sun *S*, and slides on the Wire as it approaches nearer to or recedes farther from the Sun, being nearest of all in the Perihelion *a*, and farthest in the Aphelion *g*. The areas *a S b*, *b S c*, *c S d*, &c. or contents of these several Triangles, are all equal: and in every turn of the Winch *N* the Comet *Y* is carried over one of these areas: consequently in as much time as it moves from *f* to *g*, or from *g* to *h*, it moves from *m* to *a*, or from *a* to *b*; and so of the rest, being quickest of all at *a*, and slowest at *g*. Thus, the Comet's velocity in its Orbit continually decreases from the Perihelion *a* to the Aphelion *g*; and increases in the same proportion from *g* to *a*.

The elliptic Orbit is divided into 12 equal Parts or Signs, with their respective degrees, and so is the Circle *n o p q r s t n*, which represents a great Circle in the Heavens, and to which the Comet's motion is referred by a small knob on the point of the Wire *W*. While the Comet moves from *f* to *g* in its Orbit, it appears to move only about five degrees in this Circle, as is shewn by the small knob on the end of the Wire *W*; but in the like time, as the Comet moves from *m* to *a*, or from *a* to *b*, it appears to describe the large space *t n* or *n o* in the Heavens, either of which spaces contains 120 Degrees, or four Signs. Were the Eccentricity of of its Orbit greater, the greater ſtill would be the difference of its motion, and *vice verſâ.*

ABCDEFGHIKLMA is a circular Orbit for ſhewing the equal Motion of a body round the Sun *S*, deſcribing equal Areas *ASB*, *BSC*, &c. in equal times with thoſe of the Body *Y* in its elliptical Orbit above-mentioned; but with this difference, that the circular motion deſcribes the equal Arcs *AB*, *BC*, &c. in the ſame equal times that the elliptical Motion deſcribes the unequal Arcs *ab*, *bc*, &c.

Now, ſuppoſe the two Bodies *Y* and 1 to ſtart from the Points *a* and *A* at the ſame moment of time, and each having gone round its reſpective Orbit, to arrive at theſe Points again at the ſame inſtant, the Body *Y* will be forwarder in its Orbit than the Body 1 all the way from *a* to *g*, and from *A* to *G*; but 1 will be forwarder than *Y* through all the other half of the Orbit; and the difference is equal to the Equation of the Body *Y* in its Orbit. At the points *a*, *A*, and *g*, *G*, that is, in the Perihelion and Aphelion, they will be equal; and then the Equation vaniſhes. This ſhews why the Equation of a body moving in an elliptic Orbit, is added to the mean or ſuppoſed circular Motion from the Perihelion to the Aphelion, and ſubtracted from the Aphelion to the Perihelion, in Bodies moving round the Sun, or from the Perigee to the Apogee, and from the Apogee to the Perigee in the Moon's Motion round the Earth, according to the Precepts in the 353d Article; only we are to conſider, that when Motion is turned into Time, it reverſes the titles in the Table of *The Moon's elliptic Equation.*

This Motion is performed in the following manner by the machine. *ABC* is a wooden bar (in the box containing the wheel-work) above which are the Wheels *D* and *E*; and below it the elliptic Plates *FF* and *GG*; each Plate being fixed on an Axis in one of its Focuſes, at *E* and *K*; and the Wheel *E* is fixed on the ſame Axis with the Plate PLATE IV. Fig. V.

FF.

F F. Theſe Plates have Grooves round their edges preciſely of equal diameters to one another, and in theſe Grooves is the cat-gut ſtring *gg*, *gg* croſſing between the Plates at *h*. On *H* (the Axis of the handle or winch *N* in Fig. 4th), is an endleſs ſcrew in Fig. 5, working in the Wheels *D* and *E*, whoſe numbers of teeth being equal, and ſhould be equal to the number of lines *a S*, *b S*, *c S*, &c. in Fig. 4, they turn round their Axes in equal times to one another, and to the Motion of the elliptic Plates. For, the Wheels *D* and *E* having equal numbers of teeth, the Plate *F F*, being fixed on the ſame Axis with the Wheel *E*, and the Plate *F F* turning the equally big Plate *G G* by a cat-gut ſtring round them both, they muſt all go round their Axes in as many turns of the handle *N* as either of the Wheels has teeth.

It is eaſy to ſee, that the end *h* of the elliptical Plate *F F* being farther from its Axis *E* than the oppoſite end *i* is, muſt deſcribe a Circle ſo much the larger in proportion; and muſt therefore move through ſo much more ſpace in the ſame time; and for that reaſon the end *h* moves ſo much faſter than the end *i*, although it goes no ſooner round the Center *E*. But then, the quick moving end *h* of the Plate *FF* leads about the ſhort end *h K* of the Plate *G G* with the ſame velocity; and the ſlow moving end *i* of the Plate *F F* coming half round, as to *B*, muſt then lead the long end *k* of the Plate *GG* as ſlowly about: So that the elliptical Plate *F F* and its Axis *E* move uniformly and equally quick in every part of its revolution; but the elliptical Plate *GG*, together with its Axis *K*, muſt move very unequally in different parts of its revolution: the difference being always inverſely as the diſtance of any points of the Circumference of *G G* from its Axis at *K*; or in other words, to inſtance in two points, if the diſtance *K k* be four, five, or ſix times as great as the diſtance *K h*, the Point *h* will move in that poſition four, five, or ſix times

times as faſt as the point *k* does: when the Plate *GG* has gone half round: and ſo on for any other Eccentricity or Difference of the Diſtances *Kk* and *Kh*. The tooth *i* on the Plate *FF* falls in between the two teeth at *k* on the Plate *GG*, by which means the revolution of the latter is ſo adjuſted to that of the former, that they can never vary from one another.

On the top of the Axis of the equally moving Wheel *D*, in Fig. 5th, is the Sun *S* in Fig. 4th; which Sun, by the Wire *Z* fixed to it, carries the Ball 1 round the Circle *AB CD*, &c. with an equable Motion, according to the order of the letters: and on the top of the Axis *K* of the unequally moving Ellipſis *GG*, in Fig. 5th, is the Sun *S* in Fig. 4th, carrying the Ball *Y* unequally round in the elliptical Groove *a b c d*, &c. *N. B.* This elliptical Groove muſt be preciſely equal and ſimilar to the verge of the Plate *GG*, which is alſo equal to that of *FF*.

In this manner Machines may be made to ſhew the true Motion of the Moon about the Earth, or of any Planet about the Sun; by making the elliptical Plates of the ſame Eccentricities, in proportion to the Radius, as the Orbits of the Planets are whoſe Motions they repreſent; and ſo, their different Equations, in different parts of their Orbits, may be made plain to the ſight: and clearer ideas of theſe Motions and Equations will be acquired in half an hour, than could be gained from reading half a day about them.

401. The IMPROVED CELESTIAL GLOBE. On the North Pole of the Axis, above the Hour-Circle, is fixed an Arch *MKH* of $23\frac{1}{2}$ Degrees; and at the end *H* is fixed an upright pin *HG*, which ſtands directly over the North Pole of the Ecliptic, and perpendicular to that part of the ſurface of the Globe. On this pin are two moveable Collets at *D* and *H*, to which are fixed the quadrantal Wires *N* and

The improved CELESTIAL GLOBE.

PLATE III. Fig. III.

N and *O*, having two little Balls on their ends for the Sun and Moon, as in the Figure. The Collet *D* is fixed to the circular Plate *F*, on which the 29½ days of the Moon's age are engraven, beginning juſt under the Sun's Wire *N*: and as this Wire is moved round the Globe, the Plate *F* turns round with it. Theſe Wires are eaſily turned, if the ſcrew *G* be ſlackened; and when they are ſet to their proper places, the ſcrew ſerves to fix them there; ſo that when the Globe is turned, the Wires with the Sun and Moon may go round with it; and theſe two little Balls riſe and ſet at the ſame times, and on the ſame points of the Horizon, for the day to which they are rectified, as the Sun and Moon do in the Heavens.

Becauſe the Moon keeps not her courſe in the Ecliptic (as the Sun appears to do), but has a Declination of 5⅓ Degrees, on each ſide, from it in every Lunation, § 317, her Ball may be ſcrewed as many degrees to either ſide of the Ecliptic as her Latitude, or Declination from the Ecliptic, amounts to, at any given time: and for this purpoſe *S* is a ſmall piece of paſteboard, of which the curved edge at *S* is to be ſet upon the Globe, at right Angles to the Ecliptic, and the dark line over *S* to ſtand upright upon it. From this line, on the convex edge, are drawn the 5⅓ Degrees of the Moon's Latitude on both ſides of the Ecliptic; and when this piece is ſet upright on the Globe, its graduated edge reaches to the Moon on the Wire *O*, by which means ſhe is eaſily adjuſted to her Latitude found by an Ephemeris.

The Horizon is ſupported by two ſemicircular Arches, becauſe Pillars would ſtop the progreſs of the Balls, when they go below the Horizon in an oblique ſphere.

To rectify it.

To rectify this Globe. Elevate the Pole to the Latitude of the Place; then bring the Sun's place in the Ecliptic for the given day to the braſs Meridian, and ſet the Hour-Index to XII at noon, that

that is, to the upper XII on the Hour-Circle, keeping the Globe in that ſituation; ſlacken the ſcrew *G*, and ſet the Sun directly over his place on the Meridian; which being done, ſet the Moon's Wire under the number that expreſſes her age for that day on the Plate *F*, and ſhe will then ſtand over her place in the Ecliptic, and ſhew what Conſtellation ſhe is in. Laſtly, faſten the ſcrew *G*, and laying the curved edge of the paſteboard *S* over the Ecliptic, below the Moon, adjuſt the Moon to her Latitude over the graduated edge of the paſteboard; and the Globe will be rectified.

Having thus rectified the Globe, turn it round, and obſerve on what points of the Horizon the Sun and Moon Balls riſe and ſet, for theſe agree with the points of the Compaſs on which the Sun and Moon riſe and ſet in the Heavens on the given day: and the Hour-Index ſhews the times of their riſing and ſetting; and likewiſe the time of the Moon's paſſing over the Meridian. Its uſe.

This ſimple Apparatus ſhews all the varieties that can happen in the riſing and ſetting of the Sun and Moon; and makes the forementioned Phenomena of the Harveſt-Moon (Chap. xvi.) plain to the eye. It is alſo very uſeful in reading Lectures on the Globes, becauſe a large company can ſee this Sun and Moon go round riſing above and ſetting below the Horizon at different times, according to the ſeaſons of the year; and making their appulſes to different fixed Stars. But in the uſual way, where there is only the places of the Sun and Moon in the Ecliptic to keep the eye upon, they are eaſily loſt ſight of, unleſs they be covered with patches.

402. The PLANETARY GLOBES. In this Machine, *T* is a terreſtrial Globe fixed on its Axis ſtanding upright on the Pedeſtal *CDE*, on which is an Hour-Circle, having its Index fixed on the Axis, which turns ſomewhat tightly in the Pedeſtal The PLANETARY GLOBE. PL. VIII. Fig. IV.

 ſo

ſo that the Globe may not be liable to ſhake; to prevent which, the Pedeſtal is about two Inches thick, and the Axis goes quite through it, bearing on a ſhoulder. The Globe is hung in a graduated brazen Meridian, much in the uſual way; and the thin Plate *N*, *NE*, *E* is a moveable Horizon, graduated round the outer edge, for ſhewing the Bearings and Amplitudes of the Sun, Moon, and Planets. The brazen Meridian is grooved round the outer edge; and in this Groove is a ſlender ſemi-circle of braſs, the ends of which are fixed to the Horizon in its North and South Points: this ſemi-circle ſlides in the Groove as the Horizon is moved in rectifying it for different Latitudes. To the middle of the ſemi-circle is fixed a Pin, which always keeps in the Zenith of the Horizon, and on this Pin, the Quadrant of Altitude *q* turns; the lower end of which, in all poſitions, touches the Horizon as it is moved round the ſame. This Quadrant is divided into 90 Degrees from the Horizon to the Zenithal Pin on which it is turned, at 90. The great flat Circle or Plate *AB* is the Ecliptic, on the outer edge of which the Signs and Degrees are laid down; and every fifth Degree is drawn through the reſt of the ſurface of this Plate towards its Center. On this Plate are ſeven Grooves, to which ſeven little Balls are adjuſted by ſliding Wires, ſo that they are eaſily moved in the Grooves, without danger of ſtarting out of them. The Ball next the terreſtrial Globe is the Moon, the next without it is Mercury, the next Venus, the next the Sun, then Mars, then Jupiter, and laſtly Saturn; and in order to know them, they are ſeperately ſtampt with the following Characters; ☾, ☿, ♀, ☉, ♂, ♃, ♄. This Plate or Ecliptic is ſupported by four ſtrong Wires, having their lower ends fixed into the Pedeſtal, at *C*, *D*, and *E*, the fourth being hid by the Globe. The Ecliptic is inclined $23\frac{1}{2}$ Degrees to the Pedeſtal, and is therefore properly inclined to the Axis of the Globe which ſtands upright on the Pedeſtal.

To rectify this Machine. Set the Sun, and all the Planetary Balls, to their geocentric places in the Ecliptic for any given time, by an Ephemeris; then ſet the North Point of the Horizon to the Latitude of your place on the brazen Meridian, and the Quadrant of Altitude to the South Point of the Horizon; which done, turn the Globe with its Furniture till the Quadrant of Altitude comes right againſt the Sun, viz. to his place in the Ecliptic; and keeping it there, ſet the Hour-Index to the XII next the letter *C*; and the Machine will be rectified, not only for the following Problems, but for ſeveral others, which the Artiſt may eaſily find out.

PROBLEM I.

To find the Amplitudes, Meridian Altitudes, and times of riſing, culminating, and ſetting, of the Sun, Moon, and Planets.

Turn the Globe round eaſtward, or according to the order of the Signs; and when the eaſtern edge of the Horizon comes right againſt the Sun, Moon, or any Planet, the Hour-Index will ſhew the time of its riſing; and the inner edge of the Ecliptic will cut its riſing Amplitude in the Horizon. Turn on, and when the Quadrant of Altitude comes right againſt the Sun, Moon, or any Planet, the Ecliptic will cut their Meridian Altitudes on the Quadrant, and the Hour-Index will ſhew the times of their coming to the Meridian. Continue turning, and when the Weſtern edge of the Horizon comes right againſt the Sun, Moon, or any Planet, their ſetting Amplitudes will be cut on the Horizon by the Ecliptic; and the times of their ſetting will be ſhewn by the Index on the Hour-Circle. Its uſe.

PROBLEM II.

To find the Altitude and Azimuth of the Sun, Moon, and Planets, at any time of their being above the Horizon.

Turn the Globe till the Index comes to the given time in the Hour-Circle; then keep the Globe ſteady, and moving the Quadrant of Altitude to each Planet reſpectively, the edge of the Ecliptic will cut the Planet's mean Altitude on the Quadrant, and the Quadrant will cut the Planet's Azimuth, or Point of bearing on the Horizon.

PROBLEM III.

The Sun's Altitude being given at any time either before or after Noon, to find the Hour of the Day, and the Variation of the Compaſs, in any known Latitude.

With one hand hold the edge of the Quadrant right againſt the Sun; and, with the other hand, turn the Globe weſtward, if it be in the forenoon, or eaſtward if it be in the afternoon, until the Sun's place at the inner edge of the Ecliptic cuts the Quadrant in the Sun's obſerved Altitude; and then the Hour-Index will point out the time of the day, and the Quadrant will cut the true Azimuth, or Bearing of the Sun for that time: the difference between which, and the Bearing ſhewn by the Azimuth Compaſs, is the Variation of the Compaſs in that place of the Earth.

The TRAJECTORIUM LUNARE.

403. The TRAJECTORIUM LUNARE. This Machine is for delineating the Paths of the Earth and Moon, ſhewing what ſort of Curves they make in the ethereal regions; and was juſt mentioned in the

the 266th Article. *S* is the Sun, and *E* the Earth, whofe Centers are 81 Inches diftant from each other; every Inch anfwering to a Million of Miles, § 47. *M* is the Moon, whofe Center is $\frac{24}{100}$ parts of an Inch from the Earth's in this Machine, this being in juft proportion to the Moon's diftance from the Earth, § 52. *AA* is a Bar of Wood, to be moved by hand round the Axis *g*, which is fixed in the Wheel *Y*. The Circumference of this Wheel is to the Circumference of the fmall Wheel *L* (below the other end of the Bar) as 365¼ days is to 29½; or as a Year is to a Lunation. The Wheels are grooved round their edges, and in the Grooves is the cat-gut ftring *GG* croffing between the Wheels at *X*. On the Axis of the Wheel *L*. is the Index *F*; in which is fixed the Moon's Axis *M* for carrying her round the Earth *E* (fixed on the Axis of the Wheel *L*) in the time that the Index goes round a Circle of 29½ equal parts, which are the Days of the Moon's age. The Wheel *Y* has the Months and Days of the year all round its Limb; and in the Bar *AA* is fixed the Index *I*, which points out the Days of the Months anfwering to the Days of the Moon's age, fhewn by the Index *F*, in the Circle of 29½ equal parts at the other end of the Bar. On the Axis of the Wheel *L* is put the piece *D*, below the Cock *C*, in which this Axis turns round; and in *D* are put the Pencils *e* and *m*, directly under the Earth *E* and Moon *M*; fo that *m* is carried round *e*, as *M* is round *E*. PLATE VII. Fig. V.

Lay the Machine on an even floor, preffing gently on the Wheel *Y*, to caufe its fpiked feet (of which two appear at *P* and *P*, the third being fuppofed to be hid from fight by the Wheel) to enter a little into the Floor, to fecure the Wheel from turning. Then lay a paper about four feet long under the Pencils *e* and *m*, crofs-wife to the Bar: which done, move the Bar flowly round the Axis *g* of the Wheel *Y*; and, as the Earth *E* goes round the Sun *S*, the Moon *M* will go round the Earth with a duly pro- Its ufe.

 portioned

portioned velocity; and the friction Wheel *W* running on the floor, will keep the Bar from bearing too heavily on the Pencils *e* and *m*, which will delineate the Paths of the Earth and Moon, as in Fig. 2d, already defcribed at large, § 266, 267. As the Index *I* points out the Days of the Months, the Index *F* fhews the Moon's age on thefe Days, in the Circle of $29\frac{1}{2}$ equal parts. And as this laft Index points to the different days in its Circle, the like numeral Figures may be fet to thofe parts of the curves of the Earth's Path and Moon's, where the Pencils *e* and *m* are at thofe times refpectively, to fhew the Places of the Earth and Moon. If the Pencil *e* be pufhed a very little off, as if from the Pencil *m*, to about $\frac{1}{40}$ part of their diftance, and the Pencil *m* pufhed as much toward *e* to bring them to the fame diftance again, though not to the fame points of fpace; then, as *m* goes round *e*, *e* will go as it were round the Center of Gravity between the Earth *e* and Moon *m*, § 298: but this motion will not fenfibly alter the Figure of the Earth's Path or the Moon's.

If a Pin, as *p*, be put through the Pencil *m*, with its head toward that of the Pin *q* in the Pencil *e*, the head of the former will always keep to the head of the latter as *m* goes round *e*, and fhews that the fame fide of the Moon is continually turned to the Earth. But the Pin *p*, which may be confidered as an equatorial Diameter of the Moon, will turn quite round the point *m*, making all poffible Angles with the Line of its Progrefs, or Line of the Moon's Path. This is an ocular proof of the Moon's turning round her Axis.

The TIDE-DIAL. PLATE IX. Fig. VII.

404. The TIDE-DIAL. The outfide parts of this Machine confift of, 1. An eight-fided Box, on the top of which at the corners is fhewn the Phafes of the Moon at the Octants, Quarters, and Full. Within thefe is a Circle of $29\frac{1}{2}$ equal parts, which are the days of the Moon's age accounted from the Sun at New Moon, round to the Sun again. Within this

this Circle is one of 24 hours divided into their respective Halves and Quarters. 2. A moving elliptical Plate, painted Blue, to represent the rising of the Tides under and opposite to the Moon; and has the words, *High Water*, *Tide falling*, *Low Water*, *Tide rising*, marked upon it. To one end of this Plate is fixed the Moon *M* by the Wire *W*, and goes along with it. 3. Above this elliptical Plate is a round one, with the points of the Compass upon it, and also the names of above 200 places in the large Machine (but only 32 in the Figure, to avoid confusion) set over those Points on which the Moon bears when she raises the Tides to the greatest heights at these Places twice in every lunar day: and to the North and South Points of this Plate are fixed two Indexes, *I* and *K*, which shew the times of High Water, in the Hour-Circle, at all these places. 4. Below the elliptical Plate are four small Plates, two of which project out from below its ends at New and Full Moon; and so, by lengthening the Ellipse, shew the Spring Tides, which are then raised to the greatest heights by the united attractions of the Sun and Moon, § 302. The other two of these small Plates appear at low water when the Moon is in her Quadratures, or at the sides of the elliptical Plate, to shew the Neap-Tides; the Sun and Moon then acting cross-wise to each other. When any two of these small Plates appear, the other two are hid; and when the Moon is in her Octants, they all disappear, there being neither Spring nor Neap-Tides at those times. Within the Box are a few Wheels for performing these Motions by the Handle or Winch *H*. Its use.

Turn the Handle until the Moon *M* comes to any given day of her age in the Circle of $29\frac{1}{2}$ equal parts, and the Moon's Wire *W* will cut the time of her coming to the Meridian on that day, in the Hour-Circle; the XII under the Sun being Midday, and the opposite XII Midnight; then looking for the name of any given place on the round Plate (which

(which makes $29\frac{1}{2}$ rotations while the Moon *M* makes only one revolution from the Sun to the Sun again) turn the Handle till *that* place comes to the word *High Water* under the Moon, and the Index which falls among the Forenoon Hours will ſhew the time of High Water at that place in the Forenoon of the given day: then turn the Plate half round, till the ſame place comes to the oppoſite High Water Mark, and the Index will ſhew the time of High Water in the Afternoon at that place. And thus, as all the different places come ſucceſſively under and oppoſite to the Moon, the Indexes ſhew the times of High Water at them in both parts of the day: and when the ſame places come to the Low Water Marks, the Indexes ſhew the times of Low Water. For about three days before and after the times of New and Full Moon, the two ſmall Plates come out a little way from below the High Water Marks on the elliptical Plate, to ſhew that the Tides riſe ſtill higher about theſe times: and about the Quarters, the other two Plates come out a little from under the Low Water Marks toward the Sun and on the oppoſite ſide, ſhewing that the Tides of Flood riſe not then ſo high, nor do the Tides of Ebb fall ſo low, as at other times.

By pulling the Handle a little way outward, it is diſengaged from the Wheel-work, and then the upper Plate may be turned round quickly by hand; ſo as the Moon may be brought to any given day of her age in about a quarter of a minute: and by puſhing in the Handle, it takes hold of the Wheel-work again.

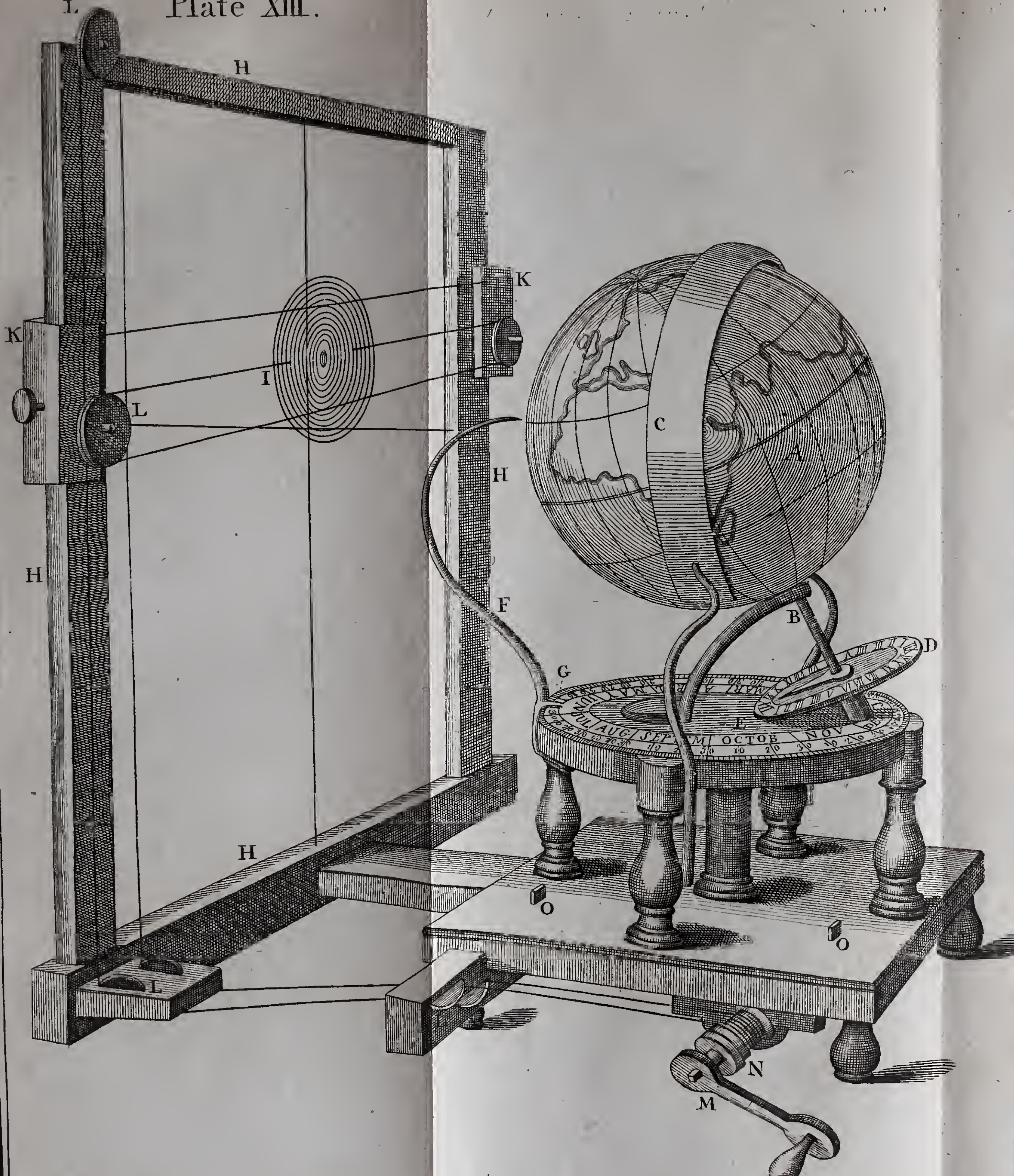
The inſide work deſcribed.

On *AB*, the Axis of the Handle *H*, is an endleſs Screw *C*, which turns the wheel *FED* of 24 teeth round in 24 revolutions of the Handle: this Wheel turns another, *ONG*, of 48 teeth, and on its Axis is the Pinion *PQ* of four leaves, which turns the Wheel *LKI* of 59 teeth round in $29\frac{1}{2}$ turnings or rotations of the Wheel *FED*, or in 708 revolu-

PLATE IX. Fig. VIII.

tions

Plate XIII.



J. Ferguson inv. et del.　　*J. Mynde sculp.*

tions of the Handle, which is the number of Hours in a ſynodical revolution of the Moon. The round Plate with the names of Places upon it is fixed on the Axis of the Wheel *F E D*; and the Elliptical or Tide-Plate with the Moon fixed to it is upon the Axis of the Wheel *L K I*; conſequently, the former makes 29½ revolutions in the time that the latter makes one. The whole Wheel *F E D*, with the endleſs Screw *C*, and dotted part of the Axis of the Handle *A B*, together with the dotted part of the Wheel *O N G*, lie hid below the large Wheel *L K I*.

Fig. IXth repreſents the under ſide of the Elliptical or Tide-Plate *a b c d*, with the four ſmall Plates *ABCD*, *EFGH*, *IKLM*, *NOPQ* upon it: each of which has two ſlits, as *TT*, *SS*, *RR*, *UU*, ſliding on two Pins, as *nn*, fixed in the Elliptical Plate. In the four ſmall Plates are fixed four Pins, at *W*, *X*, *Y*, and *Z*; all of which work in an Elliptic Groove *oooo* on the cover of the Box below the Elliptical Plate; the longeſt Axis of this Groove being in a right line with the Sun and Full Moon. Conſequently, when the Moon is in Conjunction or Oppoſition, the Pins *W* and *X* thruſt out the Plates *ABCD* and *IKLM* a little beyond the ends of the Elliptical Plate at *d* and *b*, to *f* and *e*; while the Pins *Y* and *Z* draw in the Plates *EFGH* and *NOPQ* quite under the Elliptic Plate to *g* and *h*. But, when the Moon comes to her firſt or third Quarter, the Elliptic Plate lies acroſs the fixed Elliptic Groove in which the Pins work; and therefore the end Plates *ABCD* and *IKLM* are drawn in below the great Plate, and the other two Plates *EFGH* and *NOPQ* are thruſt out beyond it to *a* and *c*. When the Moon is in her Octants, the Pins *V*, *X*, *Y*, *Z* are in the parts *o*, *o*, *o*, *o* of the Elliptic Groove, which parts are at a mean between the greateſt and leaſt diſtances from the Center *q*, and then all the four ſmall Plates diſappear, being hid by the great one.

405. The

The ECLIPSAREON. PL. XIII.

405. The ECLIPSAREON. This piece of Mechanism exhibits the Time, Quantity, Duration, and Progreſs of ſolar Eclipſes, at all parts of the Earth.

The principal parts of this Machine are, 1. A terreſtial Globe *A* turned round its Axis *B* by the Handle or Winch *M*; the Axis *B* inclines $23\frac{1}{2}$ Degrees, and has an Index which goes round the Hour-Circle *D* in each rotation of the Globe. 2. A circular Plate *E*, on the Limb of which the Months and Days of the year are inſerted. This Plate ſupports the Globe, and gives its Axis the ſame poſition to the Sun, or to a Candle properly placed, that the Earth's Axis has to the Sun upon any day of the year, § 338, by turning the Plate till the given Day of the Month comes to the fixed Pointer, or Annual Index *G*. 3. A crooked Wire *F*, which points toward the middle of the Earth's enlightened Diſc at all times, and ſhews to what place of the Earth the Sun is vertical at any given time. 4. A Penumbra, or thin circular Plate of braſs *I* divided into 12 Digits by 12 concentric Circles, which repreſent a Section of the Moon's Penumbra, and is proportioned to the ſize of the Globe; ſo that the ſhadow of this Plate, formed by the Sun, or a Candle placed at a convenient diſtance, with its rays tranſmitted through a convex Lens to make them fall parallel on the Globe, covers exactly all thoſe places upon it that the Moon's Shadow and Penumbra do on the Earth: ſo that the Phenomena of any ſolar Eclipſe may be ſhewn by this Machine with Candle-light almoſt as well as by the light of the Sun. 5. An upright frame *HHHH*, on the Sides of which are Scales of the Moon's Latitude or Declination from the Ecliptic. To theſe Scales are fitted two Sliders *K* and *K*, with Indexes for adjuſting the Penumbra's Center to the Moon's Latitude, as it is North or South Aſcending or Deſcending. 6. A Solar Horizon *C*, dividing the enlightened Hemiſphere of the

the Globe from that which is in the dark at any given time, and ſhewing at what places the general Eclipſe begins and ends with the riſing or ſetting Sun. 7. A handle *M*, which turns the Globe round its Axis by wheel-work, and at the ſame time moves the Penumbra acroſs the frame by threads over the Pulleys *L*, *L*, *L*, with a velocity duly proportioned to that of the Moon's ſhadow over the Earth, as the Earth turns on its Axis. And as the Moon's Motion is quicker or ſlower, according to her different diſtances from the Earth, the Penumbral Motion is eaſily regulated in the Machine by changing one of the Pulleys.

To rectify the Machine for uſe. The true time of New Moon and her Latitude being known by the foregoing Precepts, § 353, *et ſeq.* if her Latitude exceeds the number of minutes or diviſions on the Scales (which are on the ſide of the frame hid from view in the figure of the Machine) there can be no Eclipſe of the Sun at that conjunction; but if it does not, the Sun will be eclipſed to ſome places of the Earth; and, to ſhew the times and various appearances of the Eclipſe at thoſe places, proceed in order as follows. To rectify it.

To rectify the Machine for performing by the light of the Sun. 1. Move the Sliders *KK* till their Indexes point to the Moon's Latitude on the Scales, as it is North or South Aſcending or Deſcending, at that time. 2. Turn the Month-Plate *E* till the day of the given New Moon comes to the Annual Index *G*. 3. Unſcrew the Collar *N* a little on the Axis of the Handle, to looſen the contiguous ſocket on which the threads that move the Penumbra are wound; and ſet the Penumbra by hand till its Center comes to the perpendicular thread in the middle of the frame; which thread repreſents the Axis of the Ecliptic. 4. Turn the Handle till the Meridian of *London* on the Globe comes juſt under the point of the crooked Wire *F*; then ſtop, and turn the Hour Circle *D* by Hand till XII at Noon

comes

comes to its Index, and fet the Penumbra's middle to the thread. 5. Turn the Handle till the Hour-Index points to the time of New Moon in the Circle *D*; and holding it there, fcrew faft the Collar *N*. Laftly, elevate the Machine till the Sun fhines through the Sight-Holes in the fmall upright Plates *O*, *O* on the Pedeftal; and the whole Machine will be rectified.

To rectify the Machine for fhewing by Candle-light. Proceed in every refpect as above, except in that part of the laft paragraph where the Sun is mentioned; inftead of which place a Candle before the Machine, about four yards from it, fo as the fhadow of interfection of the crofs threads in the middle of the frame may fall precifely on that part of the Globe to which the crooked wire *F* points: then, with a pair of compaffes, take the diftance between the Penumbra's Center and interfection of the threads; and equal to that diftance fet the Candle higher or lower, as the Penumbra's Center is above or below the faid interfection. Laftly, place a large convex Lens between the Machine and Candle, fo as the Candle may be in the Focus of the Lens, and then the Rays will fall parallel, and caft a ftrong light on the Globe.

Its ufe. Thefe things being done (and they may be done fooner than they can be expreffed) turn the Handle backward, until the Penumbra almoft touches the fide *HF* of the frame; then turning gradually forward, obferve the following Phænomena. 1. Where the eaftern edge of the fhadow of the Penumbral Plate *I* firft touches the Globe at the folar Horizon, thofe who inhabit the correfponding part of the Earth fee the Eclipfe begin on the uppermoft edge of the Sun, juft at the time of its rifing. 2. In that place where the Penumbra's Center firft touches the Globe, the inhabitants have the Sun rifing upon them centrally eclipfed. 3. When the whole Penumbra juft falls upon the Globe, its weftern edge at the folar Horizon touches and leaves the place where the Eclipfe ends at Sun-riſe on the lowermoſt edge. Continue turning; and 4. The croſs lines in the Center of the Penumbra will go over all thoſe places on the Globe where the Sun is centrally eclipſed. 5. When the eaſtern edge of the ſhadow touches any place of the Globe, the Eclipſe begins there; when the verticle line in the Penumbra comes to any place, then is the greateſt obſcuration at that place; and when the weſtern edge of the Penumbra leaves the place, the Eclipſe ends there; the times of all which are ſhewn on the Hour-Circle; and from the beginning to the end, the Shadows of the concentric penumbral Circles ſhew the numbers of Digits eclipſed at all the intermediate times. 6. When the eaſtern edge of the Penumbra leaves the Globe at the ſolar Horizon *C*, the inhabitants ſee the Sun beginning to be eclipſed on his lowermoſt edge at its ſetting. 7. Where the Penumbra's Center leaves the Globe, the inhabitants ſee the Sun ſet centrally eclipſed. And laſtly, where the Penumbra is wholly departing from the Globe, the inhabitants ſee the Eclipſe ending on the uppermoſt part of the Sun's edge, at the time of its diſappearing in the Horizon.

N. B. If any given day of the year on the Plate *E* be ſet to the Annual Index *G*, and the Handle turned till the Meridian of any place comes under the point of the crooked Wire, and then the Hour-Circle *D* ſet by the hand till XII comes to its Index; in turning the Globe round by the Handle, when the ſaid place touches the eaſtern edge of the Hoop or ſolar Horizon *C*, the Index ſhews the time of Sun-ſetting at that place; and when the place is juſt coming out from below the other edge of the Hoop *C*, the Index ſhews the time when the evening Twilight ends to it. When the place has gone through the dark part *A*, and comes about ſo as to touch under the back of the Hoop *C*, on the

the other ſide, the Index ſhews the time when the Morning Twilight begins; and when the ſame place is juſt coming out from below the edge of the Hoop next the frame, the Index points out the time of Sun-riſing. And thus, the times of Sun-riſing and ſetting are ſhewn at all places in one rotation of the Globe, for any given day of the year: and the point of the crooked Wire *F* ſhews all the places over which the Sun paſſes vertically on that day.

A PLAIN

A

PLAIN METHOD

OF FINDING THE

DISTANCES of all the PLANETS from the SUN,

BY THE

TRANSIT of VENUS over the SUN's DISC, in the Year 1761.

TO WHICH IS SUBJOINED,

An Account of Mr. HORROX's Obſervations of the TRANSIT of VENUS in the Year 1639.

AND ALSO,

Of the DISTANCES of all the PLANETS from the SUN, as deduced from OBSERVATIONS of the TRANSIT in the Year 1761.

Pl. XIV.

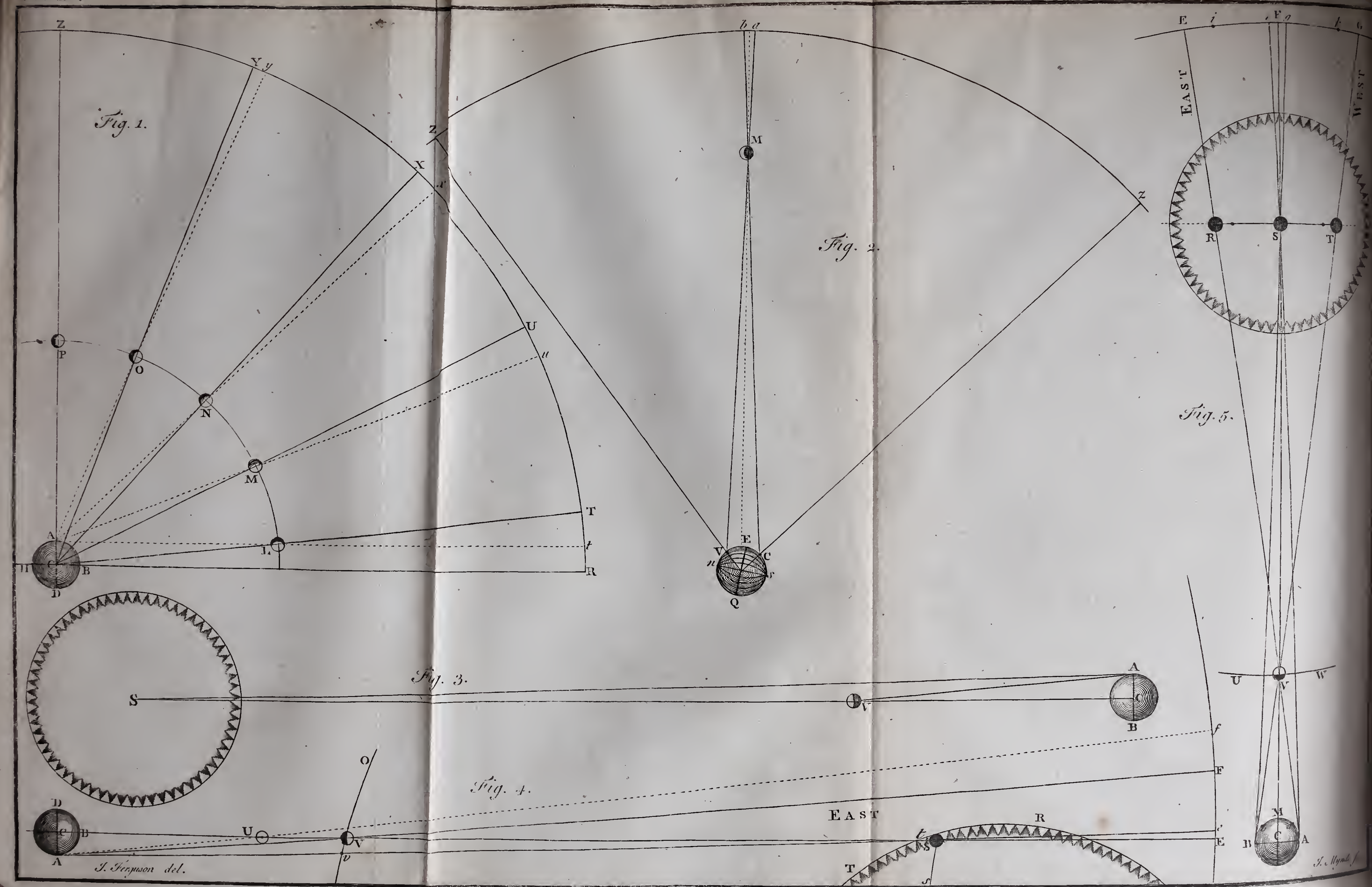


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
EAST
WEST
EAST
J. Ferguson del.
J. Mynde f.

THE

METHOD

OF FINDING THE

DISTANCES of the PLANETS from the SUN.

CHAPTER XXIII.

ARTICLE I.

Concerning Parallaxes, and their Use in general.

1. THE * approaching Tranſit of Venus over the Sun has juſtly engaged the attention of Aſtronomers, as it is a phenomenon ſeldom ſeen, and as the parallaxes of the Sun and Planets, and their diſtances from one another, may be found with greater accuracy by it, than by any other method yet known.

2. The parallax of the Sun, Moon, or any planet, is the diſtance between its true and apparent place in the heavens. The true place of any celeſtial object, referred to the ſtarry heaven, is that in which it would appear if ſeen from the center of the Earth; the apparent place is that in which it appears as ſeen from the Earth's ſurface.

To explain this, let *ABDH* be the Earth (Fig. I. of Plate XIV.), *C* its center, *M* the Moon, and *ZXR* an arc of the ſtarry heaven. To an obſerver at *C* (ſuppoſing the Earth to be tranſparent) the Moon *M* will appear at *U*, which is her true place referred to the ſtarry firmament: but at the

* The whole of this Diſſertation was publiſhed in the beginning of the year 1761, before the Time of the Tranſit, except the 7th and 8th Articles, which are added ſince that time.

 ſame

fame inftant, to an obferver at *A* fhe will appear at *u*, below her true place among the ftars.—The angle *AMC* is called the Moon's parallax, and is equal to the oppofite angle *UMu*, whofe meafure is the celeftial arc *Uu*.—The whole earth is but a point if compared with its diftance from the fixed ftars, and therefore we confider the ftars as having no parallax at all.

3. The nearer the object is to the horizon, the greater is its parallax; the nearer it is to the zenith, the lefs. In the horizon it is greateft of all; in the zenith it is nothing.—Thus let *ALt* be the fenfible horizon of an obferver at *A*; to him the Moon at *L* is in the horizon, and her parallax is the angle *ALC*, under which the Earth's femidiameter *AC* appears as feen from her. This angle is called the Moon's horizontal parallax, and is equal to the oppofite angle *TLt*, whofe meafure is the arc *Tt* in the ftarry heaven. As the Moon rifes higher and higher to the points *M*, *N*, *O*, *P*, in her diurnal courfe, the parallactic angles *UMu*, *XNx*, *Yoy* diminifh, and fo do the arcs *Uu*, *Xx*, *Yy*, which are their meafures, until the Moon comes to *P*; and then fhe appears in the zenith *Z* without any parallax, her place being the fame whether it be feen from *A* on the Earth's furface, or from *C* its center.

4. If the obferver at *A* could take the true meafure or quantity of the parallactic angle *ALC*, he might by that means find the Moon's diftance from the center of the Earth. For, in the plain triangle *LAC*, the fide *AC*, which is the Earth's femidiameter, the angle *ALC*, which is the Moon's horizontal parallax, and the right angle *CAL*, would be given. Therefore, by trigonometry, as the tangent of the parallactic angle *ALC* is to radius, fo is the Earth's femidiameter *AC* to the Moon's diftance *CL* from the Earth's center *C*.—But becaufe we confider the Earth's femidiameter as unity, and the logarithm of unity is nothing, fub-

tract the logarithmic tangent of the angle *ALC* from radius, and the remainder will be the logarithm of *CL*, and its correſponding number is the number of ſemidiameters of the Earth which the Moon is diſtant from the Earth's center.—Thus ſuppoſing the angle *ALC* of the Moon's horizontal parallax be 57′ 18″.

From the radius —	10.0000000
Subtract the tangent of 57′ 18″	8.2219207
And there will remain —	1.7780793;

which is the logarithm of 59.99, the number of ſemidiameters of the Earth which are equal to the Moon's diſtance from the Earth's center. Then, 59.99 being multiplied by 3985, the number of miles contained in the Earth's ſemidiameter, will give 239060 miles for the Moon's diſtance from the center of the Earth, by this parallax.

5. But the true quantity of the Moon's horizontal parallax cannot be accurately determined by obſerving the Moon in the horizon, on account of the inconſtancy of the horizontal refractions, which always vary according to the ſtate of the atmoſphere; and, at a mean rate, elevate the Moon's apparent place near the horizon half as much as her parallax depreſſes it. And therefore, to have her parallax more accurate, Aſtronomers have thought of the following method, which ſeems to be a very good one, but hath not yet been put in practice.

Let two obſervers be placed under the ſame meridian, one in the northern hemiſphere, and the other in the ſouthern, at ſuch a diſtance from each other, that the arc of the celeſtial meridian included between their two zeniths may be at leaſt 80 or 90 degrees. Let each obſerver take the diſtance of the Moon's center from his zenith, by means of an exceeding good inſtrument, at the moment of her paſſing the meridian: add theſe two zenith-diſtances of the Moon together, and their excess above the distance between the two zeniths will be the distance between the two apparent places of the Moon. Then, as the sum of the natural sines of the two zenith-distances of the Moon is to radius, so is the distance between her two apparent places to her horizontal parallax: which being found, her distance from the Earth's center may be found by the analogy mentioned in 4.

Thus, in Fig. 2. let *VECQ* be the Earth, *M* the Moon, and *Zbaz* an arc of the celestial meridian. Let *V* be *Vienna*, whose latitude *EV* is 48° 20′ north; and *C* the *Cape of Good Hope*, whose latitude *EC* is 34° 30′ south: both which latitudes we suppose to be accurately determined before-hand by the observers. As these two places are on the same meridian *nVECs*, and in different hemispheres, the sum of their latitudes 82° 50′ is their distance from each other. *Z* is the zenith of *Vienna*, and *z* the zenith of the *Cape of Good Hope*; which two zeniths are also 82° 50′ distant from each other, in the common celestial meridian *Zz*. To the observer at *Vienna*, the Moon's center will appear at *a* in the celestial meridian; and at the same instant, to the observer at the *Cape*, it will appear at *b*. Now suppose the Moon's distance *Z a* from the zenith of *Vienna* to be 38° 1′ 53″; and her distance *z b* from the zenith of the *Cape of Good Hope* to be 46° 4′ 41″: the sum of these two zenith-distances (*Za*+*z b*) is 84° 6′ 34″, from which subtract 82° 50′, the distance *Z z* between the zeniths of these two places, and there will remain 1° 16′ 34″ for the arc *b a*, or distance between the two apparent places of the Moon's center, as seen from *V* and from *C*. Then, supposing the tabular radius to be 10000000, the natural sine of 38° 1′ 53″ (the arc *Z a*) is 6160816, and the natural sine of 46° 4′ 41″ (the arc *Zb*) is 7202821; the sum of both these sines is 13363637. Say, therefore, As 13363637 is is to 10000000, ſo is 1° 16′ 34″, to 57′ 18″, which is the Moon's horizontal parallax.

If the two places of obſervation be not exactly under the ſame meridian, their difference of longitude muſt be accurately taken, that proper allowance may be made for the Moon's declination while ſhe is paſſing from the meridian of the one to the meridian of the other.

6. The Earth's diameter, as ſeen from the Moon, ſubtends an angle of double the Moon's horizontal parallax; which being ſuppoſed (as above) to be 57′ 18″, or 3438″, the Earth's diameter muſt be 1° 54′ 36″, or 6876″. When the Moon's horizontal parallax (which is variable on account of the eccentricity of her orbit) is 57′ 18″, her diameter ſubtends an angle 31′ 2″, or 1862″: therefore the Earth's diameter is to the Moon's diameter, as 6876 is to 1862; that is, as 3.69 is to 1.

And ſince the relative bulks of ſpherical bodies are as the cubes of their diameters, the Earth's bulk is to the Moon's bulk, as 49.4 is to 1.

7. The parallax, and conſequently the diſtance and bulk of any primary planet, might be found in the above manner, if the planet was near enough to the Earth, to make the difference of its two apparent places ſufficiently ſenſible: but the neareſt planet is too remote for the accuracy required. In order therefore to determine the diſtances and relative bulks of the planets with any tolerable degree of preciſion, we muſt have recourſe to a method leſs liable to error: and this the approaching tranſit of Venus over the Sun's diſc will afford us.

8. From the time of any inferior conjunction of the Sun and Venus to the next, is 583 days 22 hours 7 minutes. And, if the plane of Venus's orbit were coïncident with the plane of the ecliptic, ſhe would paſs directly between the Earth and the Sun at each inferior conjunction, and would then appear like a dark round ſpot on the Sun for about

7 hours and 3 quarters. But Venus's orbit (like the Moon's) only interſects the ecliptic in two oppoſite points, called its Nodes. And therefore one half of it is on the north ſide of the ecliptic, and the other on the ſouth: on which account, Venus can never be ſeen on the Sun, but at thoſe inferior conjunctions which happen in or near the nodes of her orbit. At all the other conjunctions, ſhe either paſſes above or below the Sun; and her dark ſide being then toward the Earth, ſhe is inviſible.—The laſt time when this planet was ſeen like a ſpot on the Sun, was on the 24th of *November*, Old Stile, in the year 1639.

ARTICLE II.

Shewing how to find the horizontal parallax of Venus by obſervation, and from thence, by analogy, the parallax and diſtance of the Sun, and of all the Planets from him.

9. In Fig. 4. of Plate XIV. let *D B A* be the Earth, *V* Venus, and *T S R* the eaſtern limb of the Sun. To an obſerver at *B*, the point *t* of that limb will be on the meridian, its place referred to the heaven will be at *E*, and Venus will appear juſt within it at *S*. But, at the ſame inſtant, to an obſerver at *A*, Venus is eaſt of the Sun, in the right line *A V F*; the point *t* of the Sun's limb appears at *e* in the heaven, and if Venus were then viſible, ſhe would appear at *F*. The angle *C V A* is the horizontal parallax of Venus, which we ſeek; and is equal to the oppoſite angle *F V E*, whoſe meaſure is the arc *F E*. *A S C* is the Sun's horizontal parallax, equal to the oppoſite angle *e S E*, whoſe meaſure is the arc *e E*: and *F A e* (the ſame as *V A v*) is Venus's horizontal parallax from the Sun, which may be found by obſerving how much later in abſolute time her total ingreſs on the Sun is, as ſeen from *A*, than as ſeen from *B*, which is the time

time ſhe takes to move from *V* to *v* in her orbit *OVv*.

10. It appears by the tables of Venus's motion and the Sun's, that at the time of her enſuing tranſit, ſhe will move 4′ of a degree on the Sun's diſc in 60 minutes of time; and therefore ſhe will move 4″ of a degree in one minute of time.

Now let us ſuppoſe, that *A* is 90° weſt of *B*, ſo that when it is noon at *B*, it will be VI in the morning at *A*; that the total ingreſs as ſeen from *B* is at 1 minute paſt XII. but that as ſeen from *A* it is at 7 minutes 30 ſeconds paſt VI: deduct 6 hours for the difference of meridians of *A* and *B*, and the remainder will be 6 minutes 30 ſeconds for the time by which the total ingreſs of Venus on the Sun at *S* is later as ſeen from *A* than as ſeen from *B*: which time being converted into parts of a degree is 26″, or the arc *Fe* of Venus's horizontal parallax from the Sun: for, as 1 minute of time is to 4 ſeconds of a degree, ſo is $6\frac{1}{2}$ minutes of time to 26 ſeconds of a degree.

11. The times in which the planets perform their annual revolutions about the Sun, are already known by obſervation.—From theſe times, and the univerſal power of gravity by which the planets are retained in their orbits, it is demonſtrable, that if the Earth's mean diſtance from the Sun be divided into 100000 equal parts, Mercury's mean diſtance from the Sun muſt be equal to 38710 of theſe parts—Venus's mean diſtance from the Sun, to 72333—Mars's mean diſtance, 152369—Jupiter's, 520096—and Saturn's, 954006. Therefore, when the number of miles contained in the mean diſtance of any planet from the Sun is known, we can, by theſe proportions, find the mean diſtance in miles of all the reſt.

12. At the time of the enſuing tranſit, the Earth's diſtance from the Sun will be 1015 (the mean diſtance being here conſidered as 1000), and Venus's diſtance from the Sun will be 726 (the mean

mean diſtance being conſidered as 723), which differences from the mean diſtances ariſe from the elliptical figure of the planets' orbits—Subtract 726 parts from 1015, and there will remain 289 parts for Venus's diſtance from the Earth at that time.

13. Now, ſince the horizontal parallaxes of the planets are * inverſely as their diſtances from the Earth's center, it is plain, that as Venus will be between the Earth and the Sun on the day of her tranſit, and conſequently her parallax will be then greater than the Sun's, if her horizontal parallax can be on that day aſcertained by obſervation, the Sun's horizontal parallax may be found, and conſequently his diſtance from the Earth.—Thus, ſuppoſe Venus's horizontal parallax ſhould be found to be 36″.3480; then, As the Sun's diſtance 1015 is to Venus's diſtance 289, ſo is Venus's horizontal parallax 36″.3480 to the Sun's horizontal parallax 10″.3493 on the day of her tranſit. And the difference of theſe two parallaxes, viz. 25″.9987 (which may be eſteemed 26″) will be the quantity of Venus's horizontal parallax from the Sun; which is one of the elements for projecting or delineating her tranſit over the Sun's diſc, as will appear further on.

To find the Sun's horizontal parallax at the time of his mean diſtance from the Earth, ſay, As 1000 parts, the Sun's mean diſtance from the Earth's center, is to 1015, his diſtance from it on the day

* To prove this, let *S* be the Sun (Fig. 3.) *V* Venus, *AB* the Earth, *C* its center, and *AC* its ſemidiameter. The angle *AVC* is the horizontal parallax of Venus, and *ASC* the horizontal parallax of the Sun. But by the property of plain triangles, as the ſine of *AVC* (or of *SVA* its ſupplement to 180) is to the ſine of *ASC*, ſo is *AS* to *AV*, and ſo is *CS* to *CV*.—*N. B.* In all angles leſs than a minute of a degree, the ſines, tangents, and arcs, are ſo nearly equal, that they may, without error, be uſed for one another. And here we make uſe of *Gardiner's* logarithmic tables, becauſe they have the ſines to every ſecond of a degree.

day of the tranſit, ſo is 10″.3493, his horizontal parallax on that day, to 10″.5045, his horizontal parallax at the time of his mean diſtance from the Earth's center.

14. The Sun's parallax being thus (or any other way ſuppoſed to be) found, at the time of his mean diſtance from the Earth, we may find his true diſtance from it, in ſemidiameters of the Earth, by the following analogy. As the ſine (or tangent of ſo ſmall an arc as that) of the Sun's parallax 10″.5045 is to radius, ſo is unity, or the Earth's ſemidiameter, to the number of ſemidiameters of the Earth that the Sun is diſtant from its center, which number, being multiplied by 3985, the number of miles contained in the Earth's ſemidiameter, will give the number of miles which the Sun is diſtant from the Earth's center.

Then, by § 11, As 100000, the Earth's mean diſtance from the Sun in parts, is to 38710, Mercury's mean diſtance from the Sun in parts, ſo is the Earth's mean diſtance from the Sun in miles to Mercury's mean diſtance from the Sun in miles.—And,

As 100000 is to 72333, ſo is the Earth's mean diſtance from the Sun in miles to Venus's mean diſtance from the Sun in miles.—Likewiſe,

As 100000 is to 152369, ſo is the Earth's mean diſtance from the Sun in miles to Mars's mean diſtance from the Sun in miles.—Again,

As 100000 is to 520096, ſo is the Earth's mean diſtance from the Sun in miles to Jupiter's mean diſtance from the Sun in miles.—Laſtly,

As 100000 is to 954006, ſo is the Earth's mean diſtance from the Sun in miles to Saturn's mean diſtance from the Sun in miles.

And thus, by having found the diſtance of any one of the planets from the Sun, we have ſufficient *data* for finding the diſtance of all the reſt.—And then, from their apparent diameters at theſe known diſtances,

distances, their real diameters and bulks may be found.

15. The Earth's diameter, as seen from the Sun, subtends an angle of double the Sun's horizontal parallax, at the time of the Earth's mean distance from the Sun; and the Sun's diameter, as seen from the Earth at that time, subtends an angle of 32′ 2″, or 1922″. Therefore, the Sun's diameter is to the Earth's diameter, as 1922 is to 21.— And since the relative bulks of spherical bodies are as the cubes of their diameters, the Sun's bulk is to the Earth's bulk, as 756058 is to 1; supposing the Sun's mean horizontal parallax to be 10″.5, as above.

16. It is plain by Fig. 4. that whether Venus be at *U* or *V*, or in any other part of the right line *BVS*, it will make no difference in the time of her total ingress on the Sun at *S*, as seen from *B*; but as seen from *A* it will. For, if Venus be at *V*, her horizontal parallax from the Sun is the arc *Fe*, which measures the angle *FAe*: but if she be nearer the Earth, as at *U*, her horizontal parallax from the Sun is the arc *fe*, which measures the angle *fAe*; and this angle is greater than the angle *FAe*, by the difference of their measures *fF*. So that, as the distance of the celestial object from the Earth is less, its parallax is the greater.

17. To find the parallax of Venus by the above method, it is necessary, 1. That the difference of meridians of the two places of observation be 90°. —2. That the time of Venus's total ingress on the Sun be when his eastern limb is either on the meridian of one of the places, or very near it.—And, 3. That each observer has his clock exactly regulated to the equal time at his place. But as it might, perhaps, be difficult to find two places on the Earth suited to the first and second of these requisites, we shall shew how this important problem may be solved by a single observer, if he be exact

as

as to his longitude, and has his clock truly adjuſted to the equal time at his place.

18. That part of Venus's orbit in which ſhe will move during her tranſit on the Sun, may be conſidered as a ſtraight line; and therefore, a plane may be conceived to paſs both through it and the Earth's center. To every place on the Earth's ſurface cut by this plane, Venus will be ſeen on the Sun in the ſame path that ſhe would deſcribe as ſeen from the Earth's center: and therefore ſhe will have no parallax of latitude, either north or ſouth; but will have a greater or leſs parallax of longitude, as ſhe is more or leſs diſtant from the meridian, at any time during her tranſit.

Matura, a town and fort on the ſouth coaſt of the iſland of *Ceylon*, will be in this plane at the time of Venus's total ingreſs on the Sun; and the Sun will then be 62°½ eaſt of the meridian of that place. Conſequently to an obſerver at *Matura*, Venus will have a conſiderable parallax of longitude eaſtward from the Sun, when ſhe would appear to touch the Sun's eaſtern limb as ſeen from the Earth's center, at which the Aſtronomical Tables ſuppoſe the obſerver to be placed, and give the times as ſeen from thence.

19. According to theſe tables, Venus's total ingreſs on the Sun will be 50 minutes after VII in the morning, at *Matura* *, ſuppoſing that place to be 80° eaſt longitude from the meridian of *London*; which is the obſerver's buſineſs to determine. Let us imagine that he finds it to be exactly ſo, but that to him the total ingreſs is at VII hours 55 minutes 46 ſeconds, which is 5 minutes 46 ſeconds later than the true calculated time of total ingreſs, as ſeen from the Earth's center. Then, as Venus's

* The time of total ingreſs at *London*, as ſeen from the Earth's center, is at 30 minutes after II in the morning; and if *Matura* be juſt 80° (or 5 hours 20 minutes) eaſt of *London*, when it is 30 minutes paſt II in the morning at *London*, it is 50 minutes paſt VII at *Matura*.

motion

motion on (or toward, or from) the Sun is at the rate of 4 minutes of a degree in an hour (by §10.) her motion must be 23″.1 of a degree in 5 minutes 46 seconds of time: and this 23″.1 is her parallax eastward, from her total ingress as seen from *Matura*, when her ingress would be total if seen from the Earth's center.

20. At VII hours 50 minutes in the morning, the Sun is 62°½ from the meridian; at VI in the morning he is 90° from it: therefore, as the sine of 62°½ is to the sine of 23″.1 (which is Venus's parallax from her true place on the Sun at VII hours 50 minutes) so is radius, or the sine of 90°, to the sine of 26″, which is Venus's horizontal parallax from the Sun at VI. In logarithms thus:

As the logarithmic sine of 62° 30′ - — -	9.9479289
Is to the logarithmic sine of 23″.1 - -	6.0481510
So is the logarithmic radius - - - - -	10.0000000
To the logarithmic sine of 26″ very nearly - -	6.1002221

Divide the Sun's distance from the Earth, 1015, by his distance from Venus 726 (§ 12.) and the quotient will be 1.3980; which being multiplied by Venus's horizontal parallax from the Sun 26″, will give 36″.3480, for her horizontal parallax as seen from the Earth at that time.—Then (by § 13.) as the Sun's distance 1015 is to Venus's distance 289, so is Venus's horizontal parallax 36″.3480 to the Sun's horizontal parallax 10″.3493—If Venus's horizontal parallax from the Sun is found by observation to be greater or less than 26″, the Sun's horizontal parallax must be greater or less than 10″.3493 accordingly.

21. And thus, by a single observation, the parallax of Venus, and consequently the parallax of the Sun, might be found, if we were sure that the Astronomical tables were quite correct as to the time of Venus's total ingress on the Sun.—But although the tables may be safely depended upon for

for ſhewing the true duration of the tranſit, which will not be quite 6 hours from the time of Venus's total ingreſs on the Sun's eaſtern limb, to the beginning of her egreſs from his weſtern; yet they may perhaps not give the true times of theſe two internal contacts: like a good common clock, which though it may be truſted to for meaſuring a few hours of time, yet perhaps it may not be quite adjuſted to the meridian of the place, and conſequently not true as to any one hour; which every one knows is generally the caſe.—Therefore, to make ſure work, the obſerver ought to watch both the moment of Venus's total ingreſs on the Sun, and her beginning of egreſs from him, ſo as to note preciſely the times between theſe two inſtants, by means of a good clock; and by comparing the interval at his place with the true calculated interval as ſeen from the Earth's center, which will be 5 hours 58 minutes, he may find the parallax of Venus from the Sun both at her total ingreſs and beginning of egreſs.

22. The manner of obſerving the tranſit ſhould be as follows:—The obſerver being provided with a good teleſcope, and a pendulum clock well adjuſted to the mean diurnal revolution of the Sun, and as near to the time at his place as conveniently may be; and having an aſſiſtant to watch the clock at the proper times, he muſt begin to obſerve the Sun's eaſtern limb through his teleſcope, twenty minutes at leaſt before the computed time of Venus's total ingreſs upon it, leſt there ſhould be an error in the time of the beginning, as given by the tables.

When he perceives a dent (as it were) to be made in the Sun's limb, by the interpoſition of the dark body of Venus, he muſt then continue to watch her through the teleſcope as the dent increaſes; and his aſſiſtant muſt watch the time ſhewn by the clock, till the whole body of the planet appears juſt within the Sun's limb: and the moment when the bright limb of the Sun appears cloſe

cloſe by the eaſt ſide of the dark limb of the planet, the obſerver, having a little hammer in his hand, is to ſtrike a blow therewith on the table or wall; the moment of which, the aſſiſtant notes by the clock, and writes it down.

Then, let the planet paſs on for about 2 hours 59 minutes, in which time it will be got to the middle of its apparent path on the Sun, and conſequently will then be at its leaſt apparent diſtance from the Sun's center; at which time, the obſerver muſt take its diſtance from the Sun's center, by means of a good micrometer, in order to aſcertain its true latitude or declination from the ecliptic, and thereby find the places of its nodes.

This done, there is but little occaſion to obſerve it any longer, until it comes ſo near the Sun's weſtern limb, as almoſt to touch it. Then the obſerver muſt watch the planet carefully with his teleſcope: and his aſſiſtant muſt watch the clock, ſo as to denote the preciſe moment of the planet's touching the Sun's limb, which the aſſiſtant knows by the obſerver's ſtriking a blow with his hammer.

23. The aſſiſtant muſt be very careful in obſerving what minute on the Dial-plate the minute-hand has paſt, when he has obſerved the ſecond-hand at the inſtant the blow was ſtruck by the hammer; otherwiſe, though he be right as to the number of ſeconds of the current minute, he may be apt to make a miſtake in the number of minutes.

24. To thoſe places where the tranſit begins before XII at noon, and ends after it, Venus will have an eaſtern parallax from the Sun at the beginning, and a weſtern parallax from the Sun at the end; which will contract the duration of the tranſit, by cauſing it to begin later, and end ſooner, at theſe places, than it does as ſeen from the Earth's center; which may be explained in the following manner.

In

In Fig. 5. of Plate XIV. let *BMA* be the Earth, *V* Venus, and *S* the Sun. The Earth's motion on its axis from weſt to eaſt, or in the direction *AMB*, carries an obſerver on that ſide contrary to the motion of Venus in her orbit, which is in the direction *UVW*, and will therefore cauſe her motion to appear quicker on the Sun's diſc, than it would appear to an obſerver placed at the Earth's center *C*, or at either of its poles. For, if Venus were to ſtand ſtill in her orbit at *V* for twelve hours, the obſerver on the Earth's ſurface would in that time be carried from *A* to *B*, through the arc *AMB*. When he was at *A*, he would ſee Venus on the Sun at *R*; when at *M*, he would ſee her at *S*; and when he was at *B*, he would ſee her at *T*: ſo that his own motion would cauſe the planet to appear in motion on the Sun through the line *RST*: which being in the direction of her apparent motion on the Sun as ſhe moves in her orbit *UW*, her motion will be accelerated on the Sun to this obſerver, juſt as much as his own motion would ſhift her apparent place on the Sun, if ſhe were at reſt in her orbit at *V*.

But as the whole duration of the tranſit, from firſt to laſt internal contact, will not be quite ſix hours; an obſerver, who has the Sun on his meridian at the middle of the tranſit, will be carried only from *a* to *b* during the whole time thereof. And therefore, the duration will be much leſs contracted by his own motion, than if the planet were to be twelve hours in paſſing over the Sun, as ſeen from the Earth's center.

25. The nearer Venus is to the Earth, the greater is her parallax, and the more will the true duration of her tranſit be contracted thereby; the farther ſhe is from the Earth, the contrary; ſo that the contraction will be in direct proportion to the parallax. Therefore, by obſerving, at proper places, how much the duration of the tranſit is leſs than its true duration at the Earth's center, where it is

5 hours 58 minutes, as given by the Aſtronomical tables, the parallax of Venus will be aſcertained.

26 The above method, (§ 17, *& ſeq.*) is much the ſame as was preſcribed long ago by Doctor Halley; but the calculations differ conſiderably from his; as will appear in the next article, which contains a tranſlation of the Doctor's whole diſſertation on that ſubject.—He had not computed his own tables when he wrote it, nor had he time before-hand to make a ſufficient number of obſervations on the motion of Venus, ſo as to determine whether the nodes of her orbit are at reſt or no; and was therefore obliged to truſt to other tables, which are now found to be erroneous.

ARTICLE III.

Containing Doctor Halley's *Diſſertation on the method of finding the Sun's parallax and diſtance from the Earth, by the tranſit of Venus over the Sun's Diſc,* June *the 6th,* 1761. *Tranſlated from the Latin in* Motte's *Abridgment of the Philoſophical Tranſactions, Vol. I. page* 243; *with additional notes.*

There are many things exceedingly paradoxical, and that ſeem quite incredible to the illiterate, which yet by means of mathematical principles may be eaſily ſolved. Scarce any problem will appear more hard and difficult, than that of determining the diſtance of the Sun from the Earth very near the truth: but even this, when we are made acquainted with ſome exact obſervations, taken at places fixed upon, and choſen before-hand, will without much labour be effected. And this is what I am now deſirous to lay before this illuſtrious Society * (which I foretell will continue for ages) that I may explain before-hand to young Aſtronomers, who may perhaps live to obſerve

* The Royal Society.

theſe

these things, a method by which the immense distance of the Sun may be truly obtained, to within a five hundredth part of what it really is.

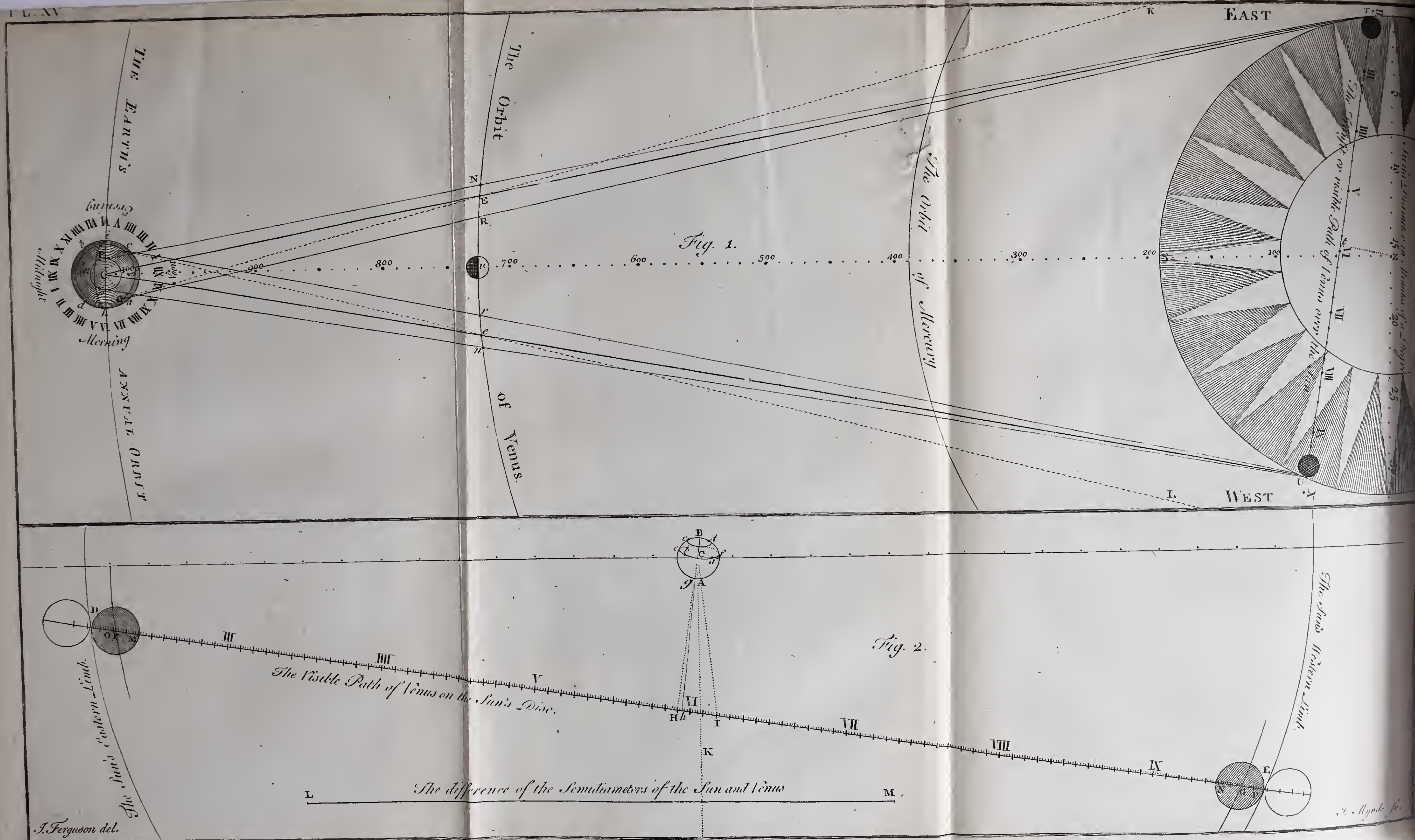
It is well known that the distance of the Sun from the Earth is by different Astronomers supposed different, according to what was judged most probable from the best conjecture that each would form. *Ptolemy* and his followers, as also *Copernicus* and *Tycho Brahe*, thought it to be 1200 semidiameters of the Earth: *Kepler* 3500 nearly: *Ricciolus* doubles the distance mentioned by *Kepler*, and *Hevelius* only increases it by one half. But the planets Venus and Mercury having, by the assistance of the telescope, been seen in the disc of the Sun, deprived of their borrowed brightness, it is at length found that the apparent diameters of the planets are much less than they were formerly supposed; and that the semidiameter of Venus seen from the Sun subtends no more than a fourth part of a minute, or fifteen seconds, while the semidiameter of Mercury, at its mean distance from the Sun, is seen under an angle only of ten seconds; that the semidiameter of Saturn seen from the Sun appears under the same angle; and that the semidiameter of Jupiter, the largest of all the planets, subtends an angle of no more than a third part of a minute at the Sun. Whence, keeping the proportion, some modern Astronomers have thought, that the semidiameter of the Earth, seen from the Sun, would subtend a mean angle between that larger one subtended by Jupiter, and that smaller one subtended by Saturn and Mercury; and equal to that subtended by Venus (namely, fifteen seconds): and have thence concluded, that the Sun is distant from the Earth almost 14000 of the Earth's semidiameters. But the same authors have on another account somewhat increased this distance: for, inasmuch as the Moon's diameter is a little more than a fourth part of the diameter of the Earth, if the Sun's parallax should be supposed fifteen ſeconds, it would follow, that the body of the Moon is larger than that of Mercury; that is, that a ſecondary planet would be greater than a primary, which would ſeem inconſiſtent with the uniformity of the mundane ſyſtem. And on the contrary, the ſame regularity and uniformity ſeems ſcarcely to admit, that Venus, an inferior planet, that has no ſatellite, ſhould be greater than our Earth, which ſtands higher in the ſyſtem, and has ſuch a ſplendid attendant. Therefore, to obſerve a mean, let us ſuppoſe the ſemidiameter of the Earth ſeen from the Sun, or, which is the ſame thing, the Sun's horizontal parallax, to be twelve ſeconds and a half; according to which, the Moon will be leſs than Mercury, and the Earth larger than Venus; and the Sun's diſtance from the Earth will come out nearly 16,500 of the Earth's ſemidiameters. This diſtance I aſſent to at preſent, as the true one, till it ſhall become certain what it is, by the Experiment which I propoſe. Nor am I induced to alter my opinion by the authority of thoſe (however weighty it may be) who are for placing the Sun at an immenſe diſtance beyond the bounds here aſſigned, relying on obſervations made upon the vibrations of a pendulum, in order to determine thoſe exceeding ſmall angles; but which, as it ſeems, are not ſufficient to be depended upon: at leaſt, by this method of inveſtigating the parallax, it will come out ſometimes nothing, or even negative; that is, the diſtance would either become infinite, or greater than infinite; which is abſurd. And indeed, to confeſs the truth, it is hardly poſſible for a man to diſtinguiſh, with any degree of certainty, ſeconds, or even ten ſeconds, with inſtruments, let them be ever ſo ſkilfully made: therefore, it is not at all to be wondered at, that the exceſſive nicety of this matter has eluded the many and ingenious endeavours of ſuch ſkilful operators.

About forty years ago, while I was in the iſland of *St. Helena*, obſerving the ſtars about the ſouth pole, I had an opportunity of obſerving, with the greateſt diligence, Mercury paſſing over the diſc of the Sun; and (which ſucceeded better than I could have hoped for) I obſerved, with the greateſt degree of accuracy, by means of a teleſcope 24 feet long, the very moment when Mercury entering upon the Sun ſeemed to touch its limb within, and alſo the moment when going off it ſtruck the limb of the Sun's diſc, forming the angle of interior contact: whence I found the interval of time, during which Mercury then appeared within the Sun's diſc, even without an error of one ſecond of time. For the lucid line intercepted between the dark limb of the planet and the bright limb of the Sun, although exceeding fine, is ſeen by the eye; and the little dent made in the Sun's limb, by Mercury's entering the diſc, appears to vaniſh in a moment; and alſo that made by Mercury, when leaving the diſc, ſeems to begin in an inſtant.— When I perceived this, it immediately came into my mind, that the Sun's parallax might be accurately determined by ſuch kind of obſervations as theſe; provided Mercury were but nearer to the Earth, and had a greater parallax from the Sun: but the difference of theſe parallaxes is ſo little, as always to be leſs than the ſolar parallax which we ſeek; and therefore Mercury, though frequently to be ſeen on the Sun, is not to be looked upon as fit for our purpoſe.

There remains then the tranſit of Venus over the Sun's diſc; whoſe parallax, being almoſt four times as great as the ſolar parallax, will cauſe very ſenſible differences between the times in which Venus will ſeem to be paſſing over the Sun at different parts of the Earth. And from theſe differences, if they be obſerved as they ought, the Sun's parallax may be determined even to a ſmall part of a ſecond. Nor do we require any other inſtruments for this purpoſe, than common teleſcopes and clocks, only good of their kind; and in the obſervers, nothing more is needful than fidelity, diligence, and a moderate ſkill in Aſtronomy. For there is no need that the latitude of the place ſhould be ſcrupulouſly obſerved, nor that the hours themſelves ſhould be accurately determined with reſpect to the meridian: it is ſufficient that the clocks be regulated according to the motion of the heavens, if the times be well reckoned from the total ingreſs of Venus into the Sun's diſc, to the beginning of her egreſs from it; that is, when the dark globe of Venus firſt begins to touch the bright limb of the Sun within; which moments, I know by my own experience, may be obſerved within a ſecond of time.

But on account of the very ſtrict laws by which the motions of the planets are regulated, Venus is ſeldom ſeen within the Sun's diſc: and during the courſe of more than 120 years, it could not be ſeen once; namely, from the year 1639 (when this moſt pleaſing ſight happened to that excellent youth, *Horrax*, our countryman, and to him only, ſince the creation) to the year 1761; in which year, according to the theories which we have hitherto found agreeable to the celeſtial motions, Venus will again paſs over the Sun on the * 26th of *May*, in the morning; ſo that at *London*, about ſix o'clock in the morning, we may expect to ſee it near the middle of the Sun's diſc, and not above four minutes of a degree ſouth of the Sun's center. But the duration of this tranſit will be almoſt eight hours; namely, from two o'clock in the morning till almoſt ten. Hence the ingreſs will not be viſible in *England*; but as the Sun will at that time be in the 16th degree of Gemini, having almoſt 23 degrees north declination, it will be ſeen without ſetting at all in almoſt all parts of the north frigid zone: and therefore the inhabitants of the coaſt of *Norway*, beyond the city of *Nidroſia*, which is called *Drontheim*, as far as the *North Cape*, will be able to obſerve Venus entering the

* The ſixth of *June*, according to the New Stile


EAST
WEST
Fig. 1.
The Earth's Annual Orbit
Evening
Midnight
Morning
The Orbit of Venus.
The Orbit of Mercury
The Ecliptic or visible Path of Venus over the Sun
Fig. 2.
The Visible Path of Venus on the Sun's Disc.
The Sun's Eastern Limb.
The Sun's Western Limb.
The difference of the Semidiameters of the Sun and Venus
J. Ferguson del.

Sun's disc; and perhaps the ingress of Venus upon the Sun, when rising, will be seen by the *Scotch*, in the northern parts of the kingdom, and by the inhabitants of the *Shetland Isles*, formerly called *Thule*. But at the time when Venus will be nearest the Sun's center, the Sun will be vertical to the northern shores of the bay of *Bengal*, or rather over the kingdom of *Pegu*; and therefore in the adjacent regions, as the Sun, when Venus enters his disc, will be almost four hours toward the east, and as many toward the west when she leaves him, the apparent motion of Venus on the Sun will be accelerated by almost double the horizontal parallax of Venus from the Sun; because Venus at that time is carried with a retrograde motion from east to west, while an eye placed upon the Earth's surface is whirled the contrary way, from west to east *.

Supposing

* This has been already taken notice of in § 24; but I shall here endeavour to explain it more at large, together with some of the following part of the Doctor's Essay, by a figure.

In Fig. 1. of Plate XV. let *C* be the center of the Earth, and *Z* the center of the Sun. In the right line *CvZ*, make *vZ* to *CZ* as 726 is to 1015 (§ 12). Let *acbd* be the Earth, *v* Venus's place in her orbit at the time of her conjunction with the Sun, and let *TSU* be the Sun, whose diameter is 31′ 42″.

The motion of Venus in her orbit is in the direction *Nvn* and the Earth's motion on its axis is according to the order of the 24 hours placed around it in the figure. Therefore, supposing the mouth of the *Ganges* to be at *G*, when Venus is at *E* in her orbit, and to be carried from *G* to *g* by the Earth's motion on its axis, while Venus moves from *E* to *e* in her orbit; it is plain that the motions of Venus and the *Ganges* are contrary to each other.

The true motion of Venus in her orbit, and consequently the space she seems to run over on the Sun's disc in any given time, could be seen only from the Earth's center *C*, which is at rest with respect to its surface. And as seen from *C*, her path on the Sun would be in the right line *TtU*; and her motion therein at the rate of four minutes of a degree in an hour. *T* is the point of the Sun's eastern limb which Venus seems to touch at the moment of her total ingress on the Sun, as seen from *C*, when Venus is at *E* in her orbit; and *U* is the point of the Sun's western limb which she seems to touch at the moment of her beginning of egress from the Sun, as seen from *C*, when she is at *e* in her orbit.

When

Suppoſing the Sun's parallax (as we have ſaid) to be $12\frac{1}{2}''$, the parallax of Venus will be $43''$; from which ſubtracting the parallax of the Sun, there will remain $30''$ at leaſt for the horizontal parallax of Venus from the Sun; and therefore the motion of Venus will be increaſed $45''$ at leaſt by that parallax, while ſhe paſſes over the Sun's diſc, in thoſe elevations of the pole which are in places near the tropic, and yet more in the neighbourhood of the equator. Now, Venus at that time will move on the Sun's diſc, very nearly at the rate of four minutes of a degree in an hour; and therefore 11 minutes of time at leaſt are to be allowed for $45''$, or three fourths of a minute of a degree;

When the mouth of the *Ganges* is at *m* (in revolving through the arc *Gmg)* the Sun is on its meridian. Therefore, ſince *G* and *g* are equally diſtant from *m* at the beginning and ending of the tranſit, it is plain that the Sun will be as far eaſt of the meridian of the *Ganges* (at *G)* when the tranſit begins, as it will be weſt of the meridian of the ſame place (revolved from *G* to *g)* when the tranſit ends.

But although the beginning of the tranſit, or rather the moment of Venus's total ingreſs upon the Sun at *T*, as ſeen from the Earth's center, muſt be when Venus is at *E* in her orbit, becauſe ſhe is then ſeen in the direction of the right line *CET*; yet at the ſame inſtant of time, as ſeen from the *Ganges* at *G*, ſhe will be ſhort of her ingreſs on the Sun, being then ſeen eaſtward of him, in the right line *GEK*, which makes the angle *KET* (equal to the oppoſite angle *GEC)*, with the right line *CET*. This angle is called the angle of Venus's parallax from the Sun, which retards the beginning of the tranſit as ſeen from the banks of the *Ganges*; ſo that the *Ganges G*, muſt advance a little farther toward *m*, and Venus muſt move on in her orbit from *E* to *R*, before ſhe can be ſeen from *G* (in the right line *GRT)* wholly within the Sun's diſc at *T*.

When Venus comes to *e* in her orbit, ſhe will appear at *U*, as ſeen from the Earth's center *C*, juſt beginning to leave the Sun; that is, at the beginning of her egreſs from his weſtern limb: but at the ſame inſtant of time, as ſeen from the *Ganges*, which is then at *g*, ſhe will be quite clear of the Sun toward the weſt; being them ſeen from *g* in the right line *geL*, which makes an angle, as *UeL* (equal to the oppoſite angle *Ceg)*, with the right line *CeU*; and this is the angle of Venus's parallax a degree; and by this ſpace of time, the duration of this eclipſe cauſed by Venus will, on account of the parallax, be ſhortened. And from this ſhortening of the time only, we might ſafely enough draw a concluſion concerning the parallax which we are in ſearch of, provided the diameter of the Sun, and the latitude of Venus, were accurately known. But we cannot expect an exact computation in a matter of ſuch ſubtilty.

We muſt endeavour therefore to obtain, if poſſible, another obſervation, to be taken in thoſe places where Venus will be in the middle of the Sun's diſc at midnight; that is, in places under the oppoſite meridian to the former, or about 6 hours or 90 degrees weſt of *London*; and where Venus enters upon the Sun a little before its ſet-

parallax from the Sun, as ſeen from the *Ganges* at *g*, when ſhe is but juſt beginning to leave the Sun at *U*, as ſeen from the Earth's center *C*.

Here it is plain, that the duration of the tranſit about the mouth of the *Ganges* (and alſo in the neighbouring places) will be diminiſhed by about double the quantity of Venus's parallax from the Sun at the beginning and ending of the tranſit. For Venus muſt be at *E* in her orbit when ſhe is wholly upon the Sun at *T*, as ſeen from the Earth's center *C*: but at that time ſhe is ſhort of the Sun, as ſeen from the *Ganges* at *G*, by the whole quantity of her eaſtern parallax from the Sun at that time, which is the angle *KET*. [This angle, in fact, is only 23″; though it is repreſented much larger in the figure, becauſe the Earth therein is a vaſt deal too big.] Now, as Venus moves at the rate of 4′ in an hour, ſhe will move 23″ in 5 minutes 45 ſeconds: and, therefore, the tranſit will begin later by 5 minutes 45 ſeconds at the banks of the *Ganges* than at the Earth's center.——When the tranſit is ending at *U*, as ſeen from the Earth's center at *C*, Venus will be quite clear of the Sun (by the whole quantity of her weſtern parallax from him) as ſeen from the *Ganges*, which is then at *g*: and this parallax will be 22″, equal to the ſpace through which Venus moves in 5 minutes 30 ſeconds of time: ſo that the tranſit will end 5½ minutes ſooner as ſeen from the *Ganges*, than as ſeen from the Earth's center.

Hence the whole contraction of the duration of the tranſit at the mouth of the *Ganges* will be 11 minutes 15 ſeconds of time: for it is 5 minutes 45 ſeconds at the beginning, and 5 minutes 30 ſeconds at the end.

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ting, and goes off a little after its riſing. And this will happen under the above-mentioned meridian, and where the elevation of the north pole is about 56 degrees; that is, in a part of *Hudſon's Bay*, near a place called *Port-Nelſon*. For, in this and the adjacent places, the parallax of Venus will increaſe the duration of the tranſit by at leaſt ſix minutes of time; becauſe, while the Sun, from its ſetting to its riſing, ſeems to paſs under the pole, thoſe places on the Earth's diſc will be carried with a motion from eaſt to weſt, contrary to the motion of the *Ganges*; that is, with a motion conſpiring with the motion of Venus; and therefore Venus will ſeem to move more ſlowly on the Sun, and to be longer in paſſing over his diſc *.

If

* In Fig. I. of Plate XV. let *aC* be the meridian of the eaſtern mouth of the *Ganges*; and *bC* the meridian of *Port-Nelſon* at the mouth of *York River* in *Hudſon's Bay*, 56° north latitude. As the meridian of the *Ganges* revolves from *a* to *c*, the meridian of *Port-Nelſon* will revolve from *b* to *d*: therefore, while the *Ganges* revolves from *G* to *g*, through the arc *Gmg*, *Port-Nelſon* revolves the contrary way (as ſeen from the Sun or Venus) from *P* to *p* through the arc *Pnp*.——Now, as the motion of Venus is from *E* to *e* in her orbit, while ſhe ſeems to paſs over the Sun's diſc in the right line *TtU*, as ſeen from the Earth's Center *C*, it is plain that while the motion of the *Ganges* is contrary to the motion of Venus in her orbit, and thereby ſhortens the duration of the tranſit at that place, the motion of *Port-Nelſon* is the ſame way as the motion of Venus, and will therefore increaſe the duration of the tranſit: which may in ſome degree be illuſtrated by ſuppoſing, that while a ſhip is under ſail, if two birds fly along the ſide of the ſhip in contrary directions to each other, the bird which flies contrary to the motion of the ſhip will paſs by it ſooner than the bird will, which flies the ſame way that the ſhip moves.

In fine, it is plain by the figure, that the duration of the tranſit muſt be longer as ſeen from *Port Nelſon*, than as ſeen from the Earth's center; and longer as ſeen from the Earth's center, than as ſeen from the mouth of the *Ganges*.——For *Port Nelſon* muſt be at *P*, and Venus at *N* in her orbit, when ſhe appears wholly within the Sun at *T*: and the ſame place muſt be at *p*, and Venus at *n*, when ſhe appears at *U*, beginning to leave the Sun.—The *Ganges* muſt be at *G*, and Venus

at

If therefore it ſhould happen that this tranſit ſhould be properly obſerved by ſkilful perſons at both theſe places, it is clear, that its duration will be 17 minutes longer, as ſeen from *Port-Nelſon*, than as ſeen from the *Eaſt-Indies*. Nor is it of much conſequence (if the *Engliſh* ſhall at that time give any attention to this affair) whether the obſervation be made at *Fort-George*, commonly called *Madras*, or at *Bencoolen* on the weſtern ſhore of the iſland of *Sumatra*, near the Equator. But if the *French* ſhould be diſpoſed to take any pains herein, an obſerver may ſtation himſelf conveniently enough at *Pondicherry* on the weſt ſhore of the bay of *Bengal*, where the altitude of the pole is about 12 degrees. As to the *Dutch*, their celebrated mart at *Batavia* will afford them a place of obſervation fit enough for this purpoſe, provided they alſo have but a diſpoſition to aſſiſt in advancing, in this particular, the knowledge of the heavens.— And indeed I could wiſh that many obſervations of the ſame phenomenon might be taken by different perſons at ſeveral places, both that we might arrive at a greater degree of certainty by their agreement, and alſo leſt any ſingle obſerver ſhould be deprived, by the intervention of clouds, of a ſight, which I know not whether any man living in this or the next age will ever ſee again; and on which depends the certain and adequate ſolution of a problem the moſt noble, and at any other time not to be attained to. I recommend it, therefore, again and again, to thoſe curious Aſtronomers, who (when I am dead) will have an opportunity of obſerving theſe things, that they would remem-

at *R*, when ſhe is ſeen from *G* upon the Sun at *T*; and the ſame place muſt be at *g*, and Venus at *r*, when ſhe begins to leave the Sun at *U*, as ſeen from *g*. So that Venus muſt move from *N* to *n* in her orbit, while ſhe is ſeen to paſs over the Sun from *Port-Nelſon*; from *E* to *e* in paſſing over the Sun, as ſeen from the Earth's center; and only from *R* to *r* while ſhe paſſes over the Sun, as ſeen from the banks of the *Ganges*.

ber

ber this my admonition, and diligently apply themſelves with all their might to the making this obſervation; and I earneſtly wiſh them all imaginable ſucceſs; in the firſt place that they may not, by the unſeaſonable obſcurity of a cloudy ſky, be deprived of this moſt deſirable ſight; and then, that having aſcertained with more exactneſs the magnitudes of the planetary orbits, it may redound to their immortal fame and glory.

We have now ſhewn, that by this method the Sun's parallax may be inveſtigated to within its five hundredth part, which doubtleſs will appear wonderful to ſome. But if an accurate obſervation be made in each of the places above marked out, we have already demonſtrated that the durations of this eclipſe made by Venus will differ from each other by 17 minutes of time; that is, upon a ſuppoſition that the Sun's parallax is $12\frac{1}{2}''$. But if the difference ſhall be found by obſervation to be greater or leſs, the Sun's parallax will be greater or leſs, nearly in the ſame proportion. And ſince 17 minutes of time are anſwerable to $12\frac{1}{2}$ ſeconds of ſolar parallax, for every ſecond of parallax there will ariſe a difference of more than 80 ſeconds of time; whence, if we have this difference true to two ſeconds, it will be certain what the Sun's parallax is to within a 40th part of one ſecond; and therefore his diſtance will be determined to within its 500dth part at leaſt, if the parallax be not found leſs than what we have ſuppoſed: for 40 times $12\frac{1}{2}$ make 500.

And now I think I have explained this matter fully, and even more than I needed to have done, to thoſe who underſtand Aſtronomy: and I would have them take notice, that on this occaſion, I have had no regard to the latitude of Venus, both to avoid the inconvenience of a more intricate calculation, which would render the concluſion leſs evident; and alſo becauſe the motion of the nodes of of Venus is not yet diſcovered, nor can be determined but by ſuch conjunctions of the planet with the Sun as this is. For we conclude that Venus will paſs 4 minutes below the Sun's center, only in conſequence of the ſuppoſition that the plane of Venus's orbit is immoveable in the ſphere of the fixed ſtars, and that its nodes remain in the ſame places where they were found in the year 1639. But if Venus, in the year 1761, ſhould move over the Sun in a path more to the ſouth, it will be manifeſt that her nodes have moved backward among the fixed ſtars; and if more to the north, that they have moved forward; and that at the rate of 5½ minutes of a degree in 100 Julian years, for every minute that Venus's path ſhall be more or leſs diſtant than the above ſaid 4 minutes from the Sun's center. And the difference between the duration of theſe eclipſes will be ſomewhat leſs than 17 minutes of time, on account of Venus's ſouth latitude; but greater if by the motion of the nodes forward ſhe ſhould paſs on the north of the Sun's center.

But for the ſake of thoſe, who, though they are delighted with ſydereal obſervations, may not yet have made themſelves acquainted with the doctrine of parallaxes, I chuſe to explain the thing a little more fully by a ſcheme, and alſo by a calculation ſomewhat more accurate.

Let us ſuppoſe that at *London*, in the year 1761, on the 6th of *June*, at 55 minutes after V in the morning, the Sun will be in Gemini 15° 37′, and therefore that at its center the ecliptic is inclined toward the north, in an angle of 6° 10′: and that the viſible path of Venus on the Sun's diſc at that time declines to the ſouth, making an angle with the ecliptic of 8° 28′; then the path of Venus will alſo be inclined to the ſouth, with reſpect to the equator, interſecting the parallels of declination

nation at an angle of 2° 18′*. Let us alſo ſuppoſe, that Venus, at the forementioned time, will be at her leaſt diſtance from the Sun's center, viz. only four minutes to the ſouth; and that every hour ſhe will deſcribe a ſpace of 4 minutes on the Sun, with a retrograde motion. The Sun's ſemidiameter will be 15′ 51″ nearly, and that of Venus 37½″. And let us ſuppoſe, for trial's ſake, that the difference of the horizontal parallaxes of Venus with the Sun (which we want) is 31″, ſuch as it comes out if the Sun's parallax be ſuppoſed 12½″. Then, on the center *C* (Plate XV. Fig. 2.) let the little circle *AB*, repreſenting the Earth's diſc, be deſcribed, and let its ſemidiameter *CB* be 31″; and let the elliptic parallels of 22 and 56 degrees of north latitude (for the *Ganges* and *Port-Nelſon*) be drawn within it, in the manner now uſed by Aſtronomers for conſtructing ſolar eclipſes. Let *BCg* be the meridian in which the Sun is, and to this, let the right line *FHG*, repreſenting the path of Venus, be inclined at an angle of 2° 18′; and let it be diſtant from the center *C* 240 ſuch parts, whereof *CB* is 31. From *C* let fall the right line *CH*, perpendicular to *FG*; and ſuppoſe Venus to be at *H* at 55 minutes after V in the morning. Let the right line *FHG* be divided into the horary ſpaces III IV, IV V, V VI, &c. each equal to *CH*; that is, to 4 minutes of a degree. Alſo, let the right line *LM* be equal to the difference of the apparent

* This was an overſight in the Doctor, occaſioned by his placing both the Earth's axis *BCg* (Fig. 2. of Plate XV.) and the Axis of Venus's orbit *CH* on the ſame ſide of the axis of the ecliptic *CK*; the former making an angle of 6° 10′ therewith, and the latter an angle of 8° 28′; the difference of which angles is only 2° 18′. But the truth is, that the Earth's axis, and the axis of Venus's orbit, will then lie on different ſides of the axis of the ecliptic, the former making an angle of 6° therewith, and the latter an angle of 8½°. Therefore, the ſum of theſe angles, which is 14½° (and not their difference 2° 18′) is the inclination of Venus's viſible path to the equator and parallels of declination.

apparent ſemidiameters of the Sun and Venus, which is 15′ 13½″; and a circle being deſcribed with the radius *LM*, on a center taken in any point within the little circle *AB* repreſenting the Earth's diſc, will meet the right line *FG* in a point denoting the time at *London* when Venus ſhall touch the Sun's limb internally, as ſeen from the place of the Earth's ſurface that anſwers to the point aſſumed in the Earth's diſc. And if a circle be deſcribed on the center *C*, with the radius *LM*, it will meet the right line *FG*, in the points *F* and *G*; and the ſpaces *FH* and *GH* will be each equal to 14′ 4″, which ſpace Venus will appear to paſs over in 3 hours 40 minutes of time at *London*; therefore, *F* will fall in II hours 15 minutes, and *G* in IX hours 35 minutes in the morning. Whence it is manifeſt, that if the magnitude of the Earth, on account of its immenſe diſtance, ſhould vaniſh as it were into a point; or, if being deprived of a diurnal motion, it ſhould always have the Sun vertical to the ſame point *C*; the whole duration of this eclipſe would be 7 hours 20 minutes. But the Earth in that time being whirled through 110 degrees of longitude, with a motion contrary to the motion of Venus, and conſequently the abovementioned duration being contracted, ſuppoſe 12 minutes, it will come out 7 hours 8 minutes, or 107 degrees, nearly.

Now, Venus will be at *H*, at her leaſt diſtance from the Sun's center, when in the meridian of the eaſtern mouth of the *Ganges*, where the altitude of the pole is about 22 degrees. The Sun therefore will be equally diſtant from the meridian of that place, at the moments of the ingreſs and egreſs of the planet, viz. 53½ degrees; as the points *a* and *b* (repreſenting that place in the Earth's diſc *AB*) are, in the greater parallel, from the meridian *BCg*. But the diameter *ef* of that parallel will be to the diſtance *ab*, as the ſquare of the radius to the rectangle under the ſines of 53½ and 68 degrees;

grees; that is, as 1′ 2″ to 46″ 13‴. And by a good calculation (which, that I may not tire the reader, it is better to omit) I find, that a circle deſcribed on *a* as a center, with the radius *LM*, will meet the right line *FII* in the point *M*, at II hours 20 minutes 40 ſeconds; but that being deſcribed round *b* as a center, it will meet *HG* in the point *N* at IX hours 29 minutes 22 ſeconds, according to the time reckoned at *London*: and therefore, Venus will be ſeen entirely within the Sun at the banks of the *Ganges* for 7 hours 8 minutes 42 ſeconds: we have then rightly ſuppoſed, that the duration will be 7 hours 8 minutes, ſince the part of a minute here is of no conſequence.

But adapting the calculation to *Port-Nelſon*, I find, that the Sun being about to ſet, Venus will enter his diſc; and immediately after his riſing ſhe will leave the ſame. That place is carried in the intermediate time through the hemiſphere oppoſite to the Sun, from *c* to *d*, with a motion conſpiring with the motion of Venus; and therefore, the ſtay of Venus on the Sun will be about 4 minutes longer, on account of the parallax; ſo that it will be at leaſt 7 hours 24 minutes, or 111 degrees of the equator. And ſince the latitude of the place is 56 degrees, as the ſquare of the radius is to the rectangle contained under the ſines $55\frac{1}{2}$ and 34 degrees, ſo is *A B*, which is 1′ 2″, to *c d*, which is 28″ 33‴. And if the calculation be juſtly made, it will appear that a circle deſcribed on *c* as a center, with the radius *LM*, will meet the right line *FH* in *O* at II hours 12 minutes 45 ſeconds; and that ſuch a circle, deſcribed on *d* as a center, will meet *HG* in *P*, at IX hours 36 minutes 37 ſeconds; and therefore the duration at *Port-Nelſon* will be 7 hours 23 minutes 52 ſeconds, which is greater than at the mouth of the *Ganges* by 15 minutes 10 ſeconds of time. But if Venus ſhould paſs over the Sun without having any latitude, the difference would be 18 minutes 40 ſeconds; and if if ſhe ſhould paſs 4′ north of the Sun's center, the difference would amount to 21 minutes 40 ſeconds, and will be ſtill greater, if the planet's north latitude be more increaſed.

From the foregoing hypotheſis it follows, that at *London*, when the Sun riſes, Venus will have entered his diſc; and that, at IX hours 37 minutes in the morning, ſhe will touch the limb of the Sun internally in going off; and laſtly, that ſhe will not entirely leave the Sun till IX hours 56 minutes.

It likewiſe follows from the ſame hypotheſis, that the center of Venus ſhould juſt touch the Sun's northern limb in the year 1769, on the third of *June*, at XI o'clock at night. So that, on account of the parallax, it will appear in the northern parts of *Norway*, entirely within the Sun, which then does not ſet to thoſe parts; while on the coaſts of *Peru* and *Chili*, it will ſeem to travel over a ſmall portion of the diſc of the ſetting Sun, and over that of the riſing Sun at the *Molucca Iſlands*, and in their neighbourhood.—But if the nodes of Venus be found to have a retrograde motion (as there is ſome reaſon to believe from ſome later obſervations they have) then Venus will be ſeen every where within the Sun's diſc; and will afford a much better method for finding the Sun's parallax, by almoſt the greateſt difference in the duration of theſe eclipſes that can poſſibly happen.

But how this parallax may be deduced from obſervations made ſomewhere in the *Eaſt-Indies*, in the year 1761, both of the ingreſs and egreſs of Venus, and compared with thoſe made in its going off with us, namely, by applying the angles of a triangle given in ſpecie to the circumference of three equal circles, ſhall be explained on ſome other occaſion.

ARTICLE IV.

Shewing that the whole method proposed by the Doctor cannot be put in practice, and why.

27. In the above Dissertation, the Doctor has explained his method with great modesty, and even with some doubtfulness with regard to its full success. For he tells us, that by means of this transit, the Sun's parallax may only be determined within its five hundredth part, provided it be not less than $12\frac{1}{2}''$; that there may be a good observation made at *Port-Nelson*, as well as about the banks of the *Ganges*; and that Venus does not pass more than 4 minutes of a degree below the center of the Sun's disc.—He has taken all proper pains not to raise our expectations too high, and yet, from his well-known abilities, and character as a great Astronomer, it seems mankind in general have laid greater stress upon his method, than he ever desired them to do. Only, as he was convinced it was the best method by which this important problem can ever be solved, he recommended it warmly for that reason. He had not then made a sufficient number of observations, by which he could determine, with certainty, whether the nodes of Venus's orbit have any motion; or if they have, whether it be backward or forward with respect to the stars. And consequently, having not then made his own tables, he was obliged to calculate from the best that he could find. But those tables allow of no motion to Venus's nodes, and also reckon her conjunction with the Sun to be about half an hour too late.

28. But more modern observations prove, that the nodes of Venus's orbit have a motion backward, or contrary to the order of the signs, with respect to the fixed stars. And this motion is allowed for in the Doctor's tables, a great part of which were made from his own observations.

And

And it appears by theſe tables, that Venus will be ſo much farther paſt her deſcending node at the time of this tranſit, than ſhe was paſt her aſcending node at her tranſit in *November*, 1639; that inſtead of paſſing only four minutes of a degree below the Sun's center in this, ſhe will paſs almoſt 10 minutes of a degree below it: on which account, the line of her tranſit will be ſo much ſhortened, as will make her paſſage over the Sun's diſc about an hour and 20 minutes leſs than if ſhe paſſed only 4 minutes below the Sun's center at the middle of her tranſit. And therefore, her parallax from the Sun will be ſo much diminiſhed, both at the beginning and end of her tranſit, and at all places from which the whole of it will be ſeen, that the difference of its durations, as ſeen from them, and as ſuppoſed to be ſeen from the Earth's center, will not amount to 11 minutes of time.

29. But this is not all: for although the tranſit will begin before the Sun ſets to *Port-Nelſon*, it will be quite over before he riſes to that place next morning, on acconnt of its ending ſo much ſooner than as given by the tables to which the Doctor was obliged to truſt. So that we are quite deprived of the advantage that otherwiſe would have ariſen from obſervations made at *Port-Nelſon*.

30. In order to trace this affair through all its intricacies, and to render it as intelligible to the reader as I can, there will be an unavoidable neceſſity of dwelling much longer upon it than I could otherwiſe wiſh. And as it is impoſſible to lay down truly the parallels of latitude, and the ſituations of places at particular times, in ſuch a ſmall diſc of the Earth as muſt be projected in ſuch a ſort of diagram as the Doctor has given, ſo as to meaſure thereby the exact times of the beginning and ending of the tranſit at any given place, unleſs the Sun's diſc be made at leaſt 30 inches diameter in the projection, and to which the Doctor did not quite truſt without making ſome calculations; I

 ſhall

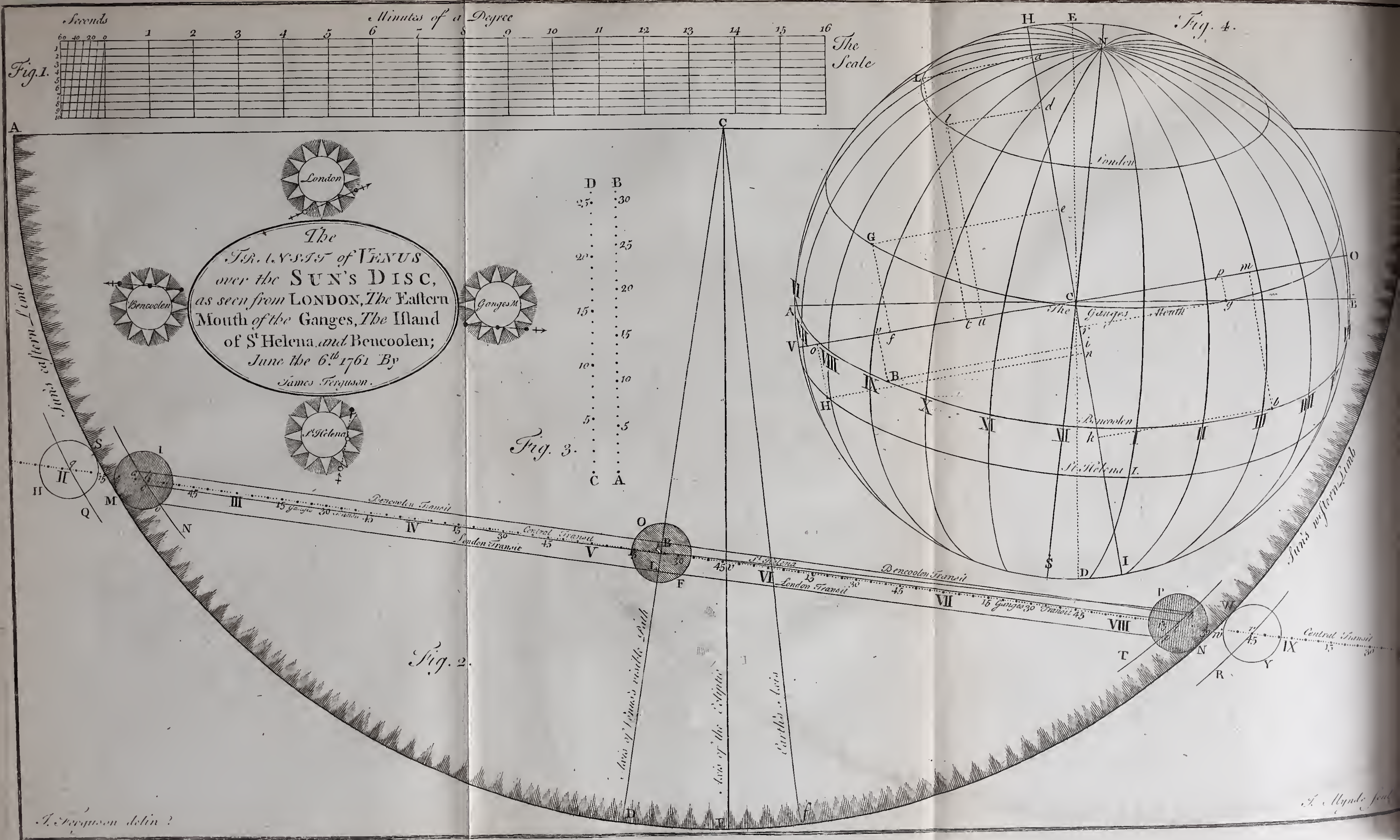
shall take a different method, in which the Earth's disc may be made as large as the operator pleases: but if he makes it only 6 inches in diameter, he may measure the quantity of Venus's parallax from the Sun upon it, both in longitude and latitude, to the fourth part of a second, for any given time and place; and then, by an easy calculation in the common rule of three, he may find the effect of the parallaxes on the duration of the transit. In this, I shall first suppose with the Doctor, that the Sun's horizontal parallax is $12\frac{1}{2}''$; and consequently, that Venus's horizontal parallax from the Sun is $31''$. And after projecting the transit, so as to find the total effect of the parallax upon its duration, I shall next shew how nearly the Sun's real parallax may be found from the observed intervals between the times of Venus's egress from the Sun, at particular places of the Earth; which is the method now taken both by the *English* and *French* Astronomers, and is a surer way whereby to come at the real quantity of the Sun's parallax, than by observing how much the whole contraction of duration of the transit is, either at *Bencoolen*, *Batavia*, or *Pondicherry*.

ARTICLE V.

Shewing how to project the transit of Venus on the Sun's disc, as seen from different places of the Earth; so as to find what its visible duration must be at any given place, according to any assumed parallax of the Sun; and from the observed intervals between the times of Venus's egress from the Sun at particular places, to find the Sun's true horizontal parallax.

31. The elements for this projection are as follows:

I. The true time of conjunction of the Sun and Venus; which, as seen from the Earth's center, and reckoned according to the equal time at *London*,


Seconds
Minutes of a Degree
The Scale
Fig. 1.
The TRANSIT of VENUS over the SUN'S DISC, as seen from LONDON, The Eastern Mouth of the Ganges, The Island of St Helena and Bencoolen; June the 6th 1761 By James Ferguson.
London
Bencoolen
Ganges M.
St Helena
Fig. 3.
Fig. 2.
Fig. 4.
Sun's eastern Limb
Sun's western Limb
Bencoolen Transit
Central Transit
London Transit
Ganges Transit
St Helena
Axis of Venus's visible Path
Axis of the Ecliptic
Earth's Axis
London
The Ganges Mouth
Bencoolen
St Helena
J. Ferguson delin.
J. Mynde sculp.

London, is on the 6th of *June* 1761, at 46 minutes 17 ſeconds after V in the morning, according to Dr. HALLEY's tables.

II. The geocentric latitude of Venus at that time, 9′ 43″ ſouth.

III. The Sun's ſemidiameter, 15′ 50″.

IV. The ſemidiameter of Venus (from the Doctor's Diſſertation) 37½″.

V. The difference of the ſemidiameters of the Sun and Venus, 15′ 12½″.

VI. Their ſum, 16′ 27½″.

VII. The viſible angle which the tranſit-line makes with the ecliptic, 8° 31′; the angular point (or deſcending node) being 1° 6′ 18″ eaſtward from the Sun, as ſeen from the Earth; the deſcending node being in ♐ 14° 29′ 37″, as ſeen from the Sun; and the Sun in ♊ 15° 35′ 55″, as ſeen from the Earth.

VIII. The angle which the Axis of Venus's viſible path makes with the axis of the ecliptic, 8° 31′; the ſouthern half of that axis being on the left hand (or eaſtward) of the axis of the ecliptic, as ſeen from the northern hemiſphere of the Earth, which would be to the right hand, as ſeen from the Sun.

IX. The angle which the Earth's axis makes with the axis of the ecliptic, as ſeen from the Sun, 6°; the ſouthern half of the Earth's axis lying to the right hand of the axis of the ecliptic, in the projection, which would be to the left hand, as ſeen from the Sun.

X. The angle which the Earth's axis makes with the axis of Venus's viſible path, 14° 31′; viz. the ſum of N° VIII. and IX.

XI. The true motion of Venus on the Sun, given by the tables as if it were ſeen from the Earth's center, 4 minutes of a degree in 60 minutes of time.

 32. Theſe

32. These elements being collected, make a scale of any convenient length, as that of Fig. 1. in Plate XVI. and divide it into 17 equal parts, each of which shall be taken for a minute of a degree; then divide the minute next to the left hand into 60 equal parts for seconds, by diagonal lines, as in the figure. The reason for dividing the scale into 17 parts or minutes is, because the sum of the semidiameters of the Sun and Venus exceeds 16 minutes of a degree. See N° VI.

33. Draw the right line *ACG* (Fig. 2.) for a small part of the ecliptic, and perpendicular to it draw the right line *CvE* for the axis of the ecliptic on the southern half of the Sun's disc.

34. Take the Sun's semidiameter, 15′ 50″, from the scale with your compasses; and with that extent, as a radius, set one foot in *C* as a center, and describe the semicircle *AEG* for the southern half of the Sun's disc; because the transit is on that half of the Sun.

35. Take the geocentric latitude of Venus, 9′ 43″, from the scale with your compasses; and set that extent from *C* to *v*, on the axis of the ecliptic: and the point *v* shall be the place of Venus's center on the Sun, at the tabular moment of her conjunction with the Sun.

36. Draw the right line *CBD*, making an angle of 8° 31′ with the axis of the ecliptic, toward the left hand; and this line shall represent the axis of Venus's geocentric visible path on the Sun.

37. Through the point of the conjunction *v*, in the axis of the ecliptic, draw the right line *qtr* for the geocentric visible path of Venus over the Sun's disc, at right angles to *CBD*, the axis of her orbit, which axis will divide the line of her path into two equal parts *qt* and *tr*.

38. Take Venus's horary motion on the Sun, 4′, from the scale with your compasses; and with that extent make marks along the transit line *qtr*. The equal spaces, from mark to mark, shew how

much of that line Venus moves through in each hour, as ſeen from the Earth's center, during her continuance on the Sun's diſc.

39. Divide each of theſe horary ſpaces, from mark to mark, into 60 equal parts for minutes of time; and ſet the hours to the proper marks in ſuch a manner, that the true time of conjunction of the Sun and Venus, 46¼ minutes after V in the morning, may fall into the point *v*, where the tranſit-line cuts the axis of the ecliptic. So the point *v* ſhall denote the place of Venus's center on the Sun, at the inſtant of her ecliptical conjunction with the Sun, and *t* (in the axis *CtD* of her orbit) will be the middle of her tranſit; which is at 24 minutes after V in the morning, as ſeen from the Earth's center, and reckoned by the equal time at *London*.

40. Take the difference of the ſemidiameters of the Sun and Venus, 15′ 12″½, in your compaſſes from the ſcale; and with that extent, ſetting one foot in the Sun's center *C*, deſcribe the arcs *N* and *T* with the other, croſſing the tranſit-line in the points *k* and *l*; which are the points on the Sun's diſc that are hid by the center of Venus at the moments of her two internal contacts with the Sun's limb or edge, at *M* and *N*: the former of theſe is the moment of Venus's total ingreſs on the Sun, as ſeen from the Earth's center, which is at 28 minutes after II in the morning, as reckoned at *London*: and the latter is the moment when her egreſs from the Sun begins, as ſeen from the Earth's center, which is 20 minutes after VIII in the morning at *London*. The interval between theſe two contacts is 5 hours 52 minutes.

41. The central ingreſs of Venus on the Sun is the moment when her center is on the Sun's eaſtern limb at *u*, which is at 15 minutes after II in the morning; and her central egreſs from the Sun is the moment when her center is on the Sun's weſtern limb at *w*; which is at 33 minutes after VIII in the

the morning, as ſeen from the Earth's center, and reckoned according to the time at *London*. The interval between theſe times is 6 hours 18 minutes.

42. Take the ſum of the ſemidiameters of the Sun and Venus, 16′ 27″½, in your compaſſes from the ſcale; and with that extent, ſetting one foot in the Sun's center *C*, deſcribe the arcs *Q* and *R* with the other, cutting the tranſit-line in the points *q* and *r*, which are the points in open ſpace (clear of the Sun) where the center of Venus is, at the moments of her two external contacts with the Sun's limb at *S* and *W*; or the moments of the beginning and ending of the tranſit, as ſeen from the Earth's center; the former of which is at 3 minutes after II in the morning at *London*, and the latter at 45 minutes after VIII. The interval between theſe moments is 6 hours 42 minutes.

43. Take the ſemidiameter of Venus 37″½, in your compaſſes from the ſcale: and with that extent as a radius, on the points *q*, *k*, *t*, *l*, *r*, as centers, deſcribe the circles *HS*, *MI*, *OF*, *PN*, *WY*, for the diſc of Venus, at her firſt contact at *S*, her total ingreſs at *M*, her place on the Sun at the middle of her tranſit, her beginning of egreſs at *N*, and her laſt contact at *W*.

44. Thoſe who have a mind to project the Earth's diſc on the Sun, round the center *C*, and to lay down the parallels of latitude and ſituations of places thereon, according to Dr. Halley's method, may draw *Cf* for the axis of the Earth, produced to the ſouthern edge of the Sun at *f*; and making an angle *ECf* of 6° with the axis of the ecliptic *CE*: but he will find it very difficult and uncertain to mark the places on that diſc, unleſs he makes the Sun's ſemidiameter *AC* 15 inches at leaſt: otherwiſe the line *Cf* is of no uſe at all in this projection.—The following method is better.

45. In Fig. 3. of Plate XVI. make the line *AB* of any convenient length, and divide it into 31 equal parts, each of which may be taken for a ſecond of

of Venus's parallax either from or upon the Sun (her horizontal parallax from the Sun being supposed to be 51″); and taking the whole length *AB* in your compasses, set one foot in *C* (Fig. 4.) as a center, and describe the circle *AEBD* for the Earth's enlightended disc, whose diameter is 62″, or double the horizontal parallax of Venus from the Sun. In this disc, draw *ACB* for a small part of the ecliptic, and at right angles to it draw *ECD* for the axis of the ecliptic. Draw also *NCS* both for the Earth's axis and universal solar meridian, making an angle of 6° with the axis of the ecliptic, as seen from the Sun; *HCI* for the axis of Venus's orbit, making an angle of 8° 31′ with *ECD*, the axis of the ecliptic; and lastly, *VCO* for a small part of Venus's orbit, at right angles to its axis.

46. This figure represents the Earth's enlightened disc, as seen from the Sun at the time of the transit. The parallels of latitude of *London*, the eastern mouth of the *Ganges*, *Bencoolen*, and the island of *St. Helena*, are laid down in it, in the same manner as they would appear to an observer on the Sun, if they were really drawn in circles on the Earth's surface (like those on a common terrestrial globe) and could be visible at such a distance.—The method of delineating these parallels is the same as already described in the XIXth Chapter, for the construction of solar eclipses.

47. The points where the curve-lines (called hour-circles) XI *N*, *XN*, &c. cut the parallels of latitude, or paths of the four places above mentioned, are the points at which the places themselves would appear in the disc, as seen from the Sun, at these hours respectively. When either places comes to the solar meridian *NCS* by the Earth's rotation on its axis, it is noon at that place; and the difference, in absolute time, between the noon at that place and the noon at any other place, is in proportion to the difference of longitude of these two places, reckoning one hour for every 15 degrees

degrees of longitude, and 4 minutes for each degree: adding the time if the longitude be east, but subtracting it if the longitude be west.

48. The distance of either of these places from *HCI* (the axis of Venus's* orbit) at any hour or part of an hour, being measured upon the scale *AB* in Fig. 3. will be equal to the parallax of Venus from the Sun in the direction of her path; and this parallax, being always contrary to the position of the place, is eastward as long as the place keeps on the left hand of the axis of the orbit of Venus, as seen from the Sun; and westward when the place gets to the right hand of that axis. So that, to all the places which are posited in the hemisphere *HVI* of the disc, at any given time, Venus has an eastern parallax; but when the Earth's diurnal motion carries the same places into the hemisphere *HOI*, the parallax of Venus is westward.

49. When Venus has a parallax toward the east, as seen from any given place on the Earth's surface, either at the time of her total ingress or beginning of egress, as seen from the Earth's center; add the time answering to this parallax to the time of ingress or egress at the Earth's center, and the sum will be the time, as seen from the given place on the Earth's surface: but when the parallax is westward, subtract the time answering to this parallax from the time of total ingress or beginning of egress, as seen from the Earth's center, and the remainder, will be the time, as seen from the given place on the surface, so far as it is affected by this parallax.—The reason of this is plain to every one

* In a former edition of this, I made a mistake, in taking the parallax in longitude instead of the parallax in the direction of the orbit of Venus; and the parallax in latitude instead of the parallax in lines perpendicular to her orbit. – But in this edition, these errors are corrected; which make some small differences in the quantities of the parallaxes, and in the times depending on them; as will appear by comparing them in this with those in the former edition.

who

who confiders, that an eaftern parallax keeps the planet back, and a weftern parallax carries it forward, with refpect to its true place or pofition, at any inftant of time, as feen from the Earth's center.

50. The neareft diftance of any given place from *VCO*, the plane of Venus's orbit at any hour or part of an hour, being meafured on the fcale *AB* in Fig. 3. will be equal to Venus's parallax in lines perpendicular to her path; which is northward from the true line of her path on the Sun, as feen from the Earth's center, if the given place be on the fouth fide of the plane of her orbit *VCO* on the Earth's difc; and the contrary, if the given place be on the north fide of that plane; that is, the parallax is always contrary to the fituation of the place on the Earth's difc, with refpect to the plane of Venus's orbit on it.

51. As the line of Venus's tranfit is on the fouthern hemifphere of the Sun's difc, it is plain that a northern parallax will caufe her to defcribe a longer line on the Sun, than fhe would if fhe had no fuch parallax; and a fouthern parallax will caufe her to defcribe a fhorter line on the Sun, than if fhe had no fuch parallax.—And the longer this line is, the fooner will her total ingrefs be, and the later will be her beginning of egrefs; and juft the contrary, if the line be fhorter.—But to all places fituated on the north fide of the plane of her orbit, in the hemifphere *VHO*, the parallax in lines perpendicular to her orbit is fouth; and to all places fituated on the fouth fide of the plane of her orbit, in the hemifphere *VIO*, this parallax is north. Therefore, the line of the tranfit will be fhorter to all places in the hemifphere *VHO*, than it will be, as feen from the Earth's center, where there is no parallax; and longer to all places in the hemifphere *VIO*. So that the time anfwering to this parallax muft be added to the time of total ingrefs, as feen from the Earth's center, and fubtracted from the beginning of egrefs, as feen from the Earth's

Earth's center, in order to have the true time of total ingrefs and beginning of egrefs as feen from places in the hemifphere *VHO:* and juft the reverfe for places in the hemifphere *VIO.*—It was proper to mention thefe circumftances, for the reader's more eafily conceiving the reafon of applying the times anfwering to thefe parallaxes in the fubfequent part of this article: for it is their fum in fome cafes, and their difference in others, which being applied to the times of total ingrefs and beginning of egrefs, as feen from the Earth's center, that will give the times of thefe phenomena as feen from given places on the Earth's furface.

52. The angle which the Sun's femidiameter fubtends, as feen from the Earth, at all times of the year, has been fo well afcertained by late obfervations, that we can make no doubt of its being 15′ 50″ on the day of the tranfit; and Venus's latitude has alfo been fo well afcertained at many different times of late, that we have very good reafon to believe it will be 9′ 43″ fouth of the Sun's center, at the time of her conjunction with the Sun.—If then her femidiameter at that time be 37″½ (as mentioned by Dr. Halley) it appears by the projection (Fig. 2.) that her total ingrefs on the Sun, as feen from the Earth's center, will be at 28 minutes after II in the morning (§ 40.), and her beginning of egrefs from the Sun will be 20 minutes after VIII, according to the time reckoned at *London.*

53. As the total ingrefs will not be vifible at *London*, we fhall not here trouble the reader about Venus's parallax at that time.—But by projecting the fituation of *London* on the Earth's difc (Fig. 4.) for the time when the egrefs begins, we find it will then be at *l*, as feen from the Sun.

Draw *ld* parallel to Venus's orbit *VCO*, and *lu* perpendicular to it: the former is Venus's eaftern parallax in the direction of her path at the beginning of her egrefs from the fun, and the latter is her

her southern parallax in a direction at right angles to her path at the same time. Take these in your compasses, and measure them on the scale *AB* (Fig. 3.) and you will find the former parallax to be $10''\frac{3}{4}$, and the latter $21''\frac{1}{2}$.

54. As Venus's true motion on the Sun is at the rate of 4 minutes of a degree in 60 minutes of time (*See* N° XI. *of* § 31.) say, as 4 minutes of a degree is to 60 minutes of time, so is $10''\frac{3}{4}$ of a degree to 2 minutes 41 seconds of time; which being added to VIII hours 20 minutes (because this parallax is eastward, § 49.) gives VIII hours 22 minutes 41 seconds, for the beginning of egress at *London*, as affected only by this parallax.—But as Venus has a southern parallax at that time, her beginning of egress will be sooner; for this parallax shortens the line of her visible transit at *London*.

55. Take the distance *Ct* (Fig. 2.), or nearest approach of the centers of the Sun and Venus, in your compasses, and measure it on the scale (Fig. 1.), and it will be found to be $9'\ 36''\frac{1}{2}$; and as the parallax of Venus from the sun in a direction which is at right angles to her path is $21''\frac{1}{2}$ south, add it to $9'\ 36''\frac{1}{2}$, and the sum will be $9'\ 58''$; which is to be taken from the scale in Fig. 1. and set from *C* to *L* in Fig. 2. And then, if a line be drawn parallel to *tl*, it will terminate at the point *p* in the arc *T*, where Venus's center will be at the beginning of her egress, as seen from *London**.—But as her center is at *l* when her egress begins as seen from the Earth's center, take *Lp* in your compasses, and setting that extent from *t* toward *l* on the central transit-line, you will find it to be 5 minutes shorter than *tl*: therefore subtract 5 minutes from VIII hours 22 minutes 41 seconds, and there will remain VIII

* The reason why the line *o L p*, *a B b*, *c t*, and *t b*, which are the visible transits at *London*, the *Ganges* mouth, *Bencoolen*, and *St. Helena*, are not parallel to the central transit line *k t l*, is, because the parallaxes in latitude are different at the times of ingress and egress, as seen from each of these places. The method of drawing these lines will be shewn by and by.

hours

hours 17 minutes 41 ſeconds for the viſible beginning of egreſs in the morning at *London*.

56. At V hours 24 minutes (which is the middle of the tranſit, as ſeen from the Earth's center) *London* will be at *L* on the Earth's diſc (Fig. 4.) as ſeen from the Sun. The parallax *La* of Venus from the Sun in the direction of her path is then 12″½; by which, working as above directed, we find the middle of the tranſit, as ſeen from *London*, will be at V hours 20 minutes 53 ſeconds.—This is not affected by *Lt* the parallax at right angles to the path of Venus.—But *Lt* meaſures 27″ on the ſcale *AB* (Fig. 3.): therefore take 27″ from the ſcale in Fig. 1. and ſet it from *t* to *L*, on the axis of Venus's path in Fig. 2. and laying a ruler to the point *L*, and the above found point of egreſs *p*, draw *oLp* for the line of the tranſit as ſeen from *London*.

57. The eaſtern mouth of the river *Ganges* is 89 degrees eaſt from the meridian of *London*; and therefore, when the time at *London* is 28 minutes after II in the moring (§ 40.) it is 24 minutes paſt VIII in the morning (by § 47) at the mouth of the *Ganges*; and when it is 20 minutes paſt VIII in the morning at *London* (§ 40.) it is 16 minutes paſt II in the afternoon at the *Ganges*. Therefore, by projecting that place upon the Earth's diſc, as ſeen from the Sun, it will be at *G* (in Fig. 4.) at the time of Venus's total ingreſs, as ſeen from the Earth's center, and at *g* when her egreſs begins.

Draw *Ge* and *gr* parallel to the orbit of Venus *VCO*, and meaſure them on the ſcale *AB* in Fig. 3. the former will be 21″ for Venus's eaſtern parallax in the direction of her path, at the above-mentioned time of her total ingreſs, and the latter will be 16″¼ for her weſtern parallax at the time when her egreſs begins.—The former parallax gives 5 minutes 15 ſeconds of time (by the analogy in § 54.) to be added to VIII hours 24 minutes, and the latter parallax gives 4 minutes 11 ſeconds to be ſubtracted from II hours 16 minutes; by which we have VIII hours

hours 29 minutes 15 ſeconds, for the time of total ingreſs, as ſeen from the banks of the *Ganges*, and II hours 11 minutes 49 ſeconds for the beginning of egreſs, as effected by theſe parallaxes.

Draw *Gf* perpendicular to Venus's orbit *VOC*, and by meaſurement on the ſcale *AB* (Fig. 3.) it will be found to contain 10″: take 10″ from the ſcale in Fig. 1. and find, by trials, a point *c*, in the arc *N*, where, if one foot of the compaſſes be placed, the other will juſt touch the central tranſit line *kl*. Take the neareſt diſtance from this point *c* to *CL*, the axis of Venus's orbit, and applying it from *t* toward *k*, you will find it fall a minute ſhort of *k*; which ſhews, that Venus's parallax in this dirction ſhortens the beginning of the line of her viſible tranſit at the *Ganges* by one minute of time. Therefore, as this makes the viſible ingreſs a minute later, add one minute to the above VIII hours 29 minutes 15 ſeconds, and it will give VIII hours 30 minues 15 ſeconds for the time of total ingreſs in the morning, as ſeen from the eaſtern mouth of the *Ganges*. At the beginning of egreſs, the parallax *gp* in the ſame direction is $2''\frac{1}{2}$ (by meaſurement on the ſcale *AB*), which will protract the beginning of egreſs by about 30 ſeconds of time, and muſt therefore be added to the above II hours 11 minutes 49 ſeconds, which will make the viſible beginning of egreſs to be at II hours 12 minutes 19 ſeconds in the afternoon.

58. *Bencoolen* is 102 degrees eaſt from the meridian of *London*; and therefore, when the time is 28 minutes paſt II in the morning at *London*, it is 16 minutes paſt IX in the morning at *Bencoolen*; and when it is 20 minutes paſt VIII in the morning at *London*, it is 8 minutes paſt III in the afternoon at *Bencoolen*. Therefore, in Fig. 4. *Bencoolen* will be at *B* at the time of Venus's total ingreſs, as ſeen from the Earth's center; and at *b* when her egreſs begins.

Draw

Draw *B i* and *b k* parallel to Venus's orbit *VCO*, and measure them on the scale: the former will be found to be 22″ for Venus's eastern parallax in the direction of her path at the time of her total ingress; and the latter to be 19″½ for her western parallax in the same direction when her egress begins, as seen from the Earth's center. The first of these parallaxes gives 5 minutes 30 seconds (by the analogy in § 54.) to be added to IX hours 16 minutes, and the latter parallax gives 4 minutes 52 seconds to be subtracted from III hours 8 minutes; whence we have IX hours 21 minues 30 seconds for the time of total ingress at *Bencoolen*: and III hours and 3 minutes 8 seconds for the time when the egress begins there, as affected by these two parallaxes.

59. Draw *Bv* and *b m* perpendicular to Venus's orbit *VCO*, and measure them on the scale *AB*: the former will be 5″ for Venus's northern parallax in a direction perpendicular to her path, as seen from *Bencoolen*, at the time of her total ingress; and the latter will be 15″½ for her northern parallax in that direction when her egress begins. Take these parallaxes from the scale, Fig. 1. in your compasses, and find, by trials, two points in the arcs *N* and *T* (Fig. 2.) where if one foot of the compasses be placed, the other will touch the central transit line *kl*: draw a line from *a* to *b*, for the line of Venus's transit as seen from *Bencoolen*; the center of Venus being at *a*, as seen from *Bencoolen*, at the moment of her total ingress; and at *b* at the moment when her egress begins.

But as seen from the Earth's center, the center of Venus is at *k* in the former case, and at *l* in the latter: so that we find the line of the transit is longer as seen from *Bencoolen* than as seen from the Earth's center, which is the effect of Venus's northern parallax.—Take *B a* in your compasses, and setting that extent backward from *t* toward *g*, on the central transit-line, you will find it will reach two minutes beyond *k*: and taking the extent *B b* in in your compaffes, and fetting it forward from *t* toward *w*, on the central tranfit-line, it will be found to reach 3 minutes beyond *l*. Confequently, if we fubtract 2 minutes from IX hours 21 minutes 30 feconds (above found), we have IX hours 19 minutes 30 feconds, in the morning, for the time of total ingrefs, as feen from *Bencoolen:* and if we add 3 minutes to the above found III hours 3 minutes 8 feconds, we fhall have III hours 6 minutes 8 feconds afternoon, for the time when the egrefs begins, as feen from *Bencoolen.*

60. The whole duration of the tranfit, from the total ingrefs to the beginning of egrefs, as feen from the Earth's center, is 5 hours 52 minutes (by § 40.) but the whole duration from the total ingrefs to the beginning of egrefs, as feen from *Bencoolen*, is only 5 hours 46 minutes 38 feconds; which is 5 minutes 22 feconds lefs than as feen from the Earth's center: and this 5 minutes 22 feconds is the whole effect of the parallaxes (both in longitude and latitude) on the duration of the tranfit at *Bencoolen.*

But the duration, as feen at the mouth of the *Ganges*, from ingrefs to egrefs, is ftill lefs; for it is only 5 hours 42 minutes 4 feconds: which is 9 minutes 56 feconds lefs than as feen from the Earth's center, and 4 minutes 34 feconds lefs than as feen at *Bencoolen.*

61. The ifland of *St. Helena* (to which only a fmall part of the tranfit is vifible at the end) will be at *H* (as in Fig. 4.) when the egrefs begins as feen from the Earth's center. And fince the middle of that ifland is 6° weft from the meridian of *London*, and the faid egrefs begins when the time at *London* is 20 minutes paft VIII in the morning, it will then be only 56 minutes paft VII in the morning at *St Helena.*

Draw *Hn* parallel to Venus's orbit *VCO*, and *Ho* perpendicular to it; and by meafuring them on the fcale *AB* (Fig. 3.) the former will be found to amount to 29″ for Venus's eaftern parallax in the direction of her path, as seen from *St. Helena*, when her egress begins, as seen from the Earth's center; and the latter to be 6″ for her northern parallax in a direction at right angles to her path.

By the analogy in § 54, the parallax in the direction of the path of Venus gives 10 minutes·2 seconds of time; which being added (on account of its being eastward) to VII hours 56 minutes, gives VIII hours 6 minutes 2 seconds for the beginning of egress at *St. Helena*, as affected by this parallax. —But 6″ of parallax in a perpendicular direction to her path (applied as in the case of *Bencoolen*) lengthens out the end of the transit-line by one minute; which being added to VIII hours 6 minutes 2 seconds, gives VIII hours 7 minutes 2 seconds for the beginning of egress, as seen from *St. Helena*.

62. We shall now collect the above-mentioned times into a small table, that they may be seen at once, as follows: *M* signifies morning, *A* afternoon.

	Total ingress. H. M. S.	Beg. of egress. H. M. S.	Duration. H. M. S.
At The Earth's center	II. 28 0*M*	VIII 20 0*M*	5 52 0*
At *London* - - -	Invisible. *M*	VIII 17 41*M*	— — —
At The *Ganges* mouth	VIII 30 15*M*	II 12 19*A*	5 42 4
At *Bencoolen* - - -	IX 19 30*M*	III 6 · 8*A*	5 46 38
At *St. Helena* - -	Invisible. *M*	VIII 7 2*M*	———

63. The times at the three last-mentioned places are reduced to the meridian of *London*, by subtracting 5 hours 56 minutes from the times of ingress and egress at the *Ganges*; 6 hours 48 minutes from the times at *Bencoolen*; and adding 24

* This duration, as seen from the Earth's center, is on supposition that the semidiameter of Venus would be found equal to 37″½, on the Sun's disc, as stated by Dr. *Halley* (see Art. V. § 31.) to which all the other durations are accommodated.—But, from later observations, is is highly probable, that the semidiameter of Venus will be found not to exceed 30″ on the Sun; and if so, the duration between the two internal contacts, as seen from the Earth's center, will be 5 hours 58 minutes; and the duration, as seen from the above mentioned places, will be lengthened very nearly in the same proportion.

minutes to the time of beginning of egreſs at *St. Helena*: and being thus reduced, they are as follows:

		Total ingreſs. H. M. S.	Beg. of egreſs. H. M. S.	
Times at *London* for	*Ganges* mouth	II 34 15 *M*	VIII 16 19 *M*	Durations as above.
	Bencoolen - -	II 31 30 *M*	VIII 18 8 *M*	
	St. Helena -	Inviſible *M*	VIII 31 2 *M*	

64. All this is on ſuppoſition, that we have the true longitudes of the three laſt-mentioned places, that the Sun's horizontal parallax is 12″½ that the true latitude of Venus is given, and that her ſemidiameter will ſubtend an angle of 37″½ on the Sun's diſc.

As for the longitudes, we muſt ſuppoſe them true, until the obſervers aſcertain them, which is a very important part of their buſineſs; and without which they can by no means find the interval of abſolute time that elapſeth between either the ingreſs or egreſs, as ſeen from any two given places: and there is much greater dependance to be had on this elapſe, than upon the whole contraction of duration at any given place, as it will undoubtedly afford a ſurer baſis for determining the Sun's parallax.

65. I have good reaſon to believe, that the latitude of Venus, as given in § 31, will be found by obſervation to be very near the truth; but that the time of conjunction there mentioned will be found later than the true time by almoſt 5 minutes; that Venus's ſemidiameter will ſubtend an angle of no more than 30″ on the Sun's diſc; and that the middle of her tranſit, as ſeen from the Earth's center, will be at 24 minutes after V in the morning, as reckoned by the equal time at *London*.

66. Subtract VIII hours 17 minutes 41 ſeconds, the time when the egreſs begins at *London*, from VIII hours 31 minutes 2 ſeconds, the time reckoned at *London* when the egreſs begins at *St. Helena*, and

there will remain 13 minutes 21 seconds (or 801 seconds) for their difference, or elapse, in absolute time, between the beginning of egress, as seen from these two places.

Divide 801 seconds by the Sun's parallax $12''\frac{1}{2}$, and the quotient will be 64 seconds and a small fraction. So that for each second of a degree in the Sun's horizontal parallax (supposing it to be $12''\frac{1}{2}$) there will be a difference or elapse of 64 seconds of absolute time between the beginning of egress as seen from *London*, and as seen from *St. Helena*; and consequently 32 seconds of time for every half second of the Sun's parallax; 16 seconds of time for every fourth part of a second of the Sun's parallax; 8 seconds of time for the eighth part of a second of the Sun's parallax; and full 4 seconds for a sixteenth part of the Sun's parallax. For, in so small an angle as that of the Sun's parallax, the arc is not sensibly different from either its sine or its tangent: and therefore, the quantity of this parallax is in direct proportion to the absolute difference in the time of egress arising from it, at different parts of the Earth.

67. Therefore, when this difference is ascertained by good observations, made at different places, and compared together, the true quantity of the Sun's parallax will be very nearly determined. For, since it may be presumed that the beginning of egress can be observed within 2 seconds of its real time, the Sun's parallax may be then found within the 32d part of a second of its true quantity; and consequently, his distance may be found within a 400th part of the whole, provided his parallax be not less than $12''\frac{1}{2}$; for 32 times $12\frac{1}{2}$ is 400.

68. But since Dr. HALLEY has assured us, that he had observed the two internal contacts of the planet Mercury with the Sun's edge so exactly, as not to err one second in the time, we may well imagine that the internal contacts of Venus with the Sun may be observed with as great

great accuracy. So that we may hope to have the abſolute interval beween the moments of her beginning of egreſs, as ſeen from *London* and from *St. Helena*, true to a ſecond of time; and if ſo, the Sun's parallax may be determined to the 64th part of a ſecond, provided it be not leſs than $12''\frac{1}{2}$: and conſequently his diſtance may be found, within its 800th part; for 64 times $12\frac{1}{2}$ is 800: which is ſtill nearer the truth than Dr. HALLEY expected it might be found, by obſerving the whole duration of the tranſit in the *Eaſt-Indies* and at *Port-Nelſon*. So that our preſent Aſtronomers have judiciouſly reſolved to improve the Doctor's method, by taking only the interval between the abſolute times of its ending at different places. If the Sun's parallax be greater or leſs than $12''\frac{1}{2}$, the elapſe or difference of abſolute time between the beginning of egreſs at *London* and *St. Helena*, will be found by obſervation to be greater or leſs than 801 ſeconds accordingly.

69. There will alſo be a great difference between the abſolute times of egreſs at *St. Helena* and the northern parts of *Ruſſia*, which would make theſe places very proper for obſervation. The difference between them at *Tobolſk* in *Siberia* and at *St. Helena* will be 11 minutes, according to DE L'ISLE's map: at *Archangel* it will be but about 40 ſeconds leſs than at *Tobolſk*; and only a minute and a quarter leſs at *Peterſburg*, even if the Sun's parallax be no more than $10''\frac{1}{2}$. At *Wardhus* the ſame advantage would nearly be gained as at *Tobolſk*; but if the obſervers could go ſtill farther to the eaſt, as to *Yakoutſk* in *Siberia*, the advantage would be ſtill greater: for, as M. DE L'ISLE very juſtly obſerves, in a memoir preſented to the *French* king with his map of the tranſit, the difference of time between Venus's egreſs from the Sun at *Yakoutſk* and at the *Cape of Good Hope* will be $13\frac{1}{2}$ minutes.

70. This method requires that the longitude of each place of obſervation be aſcertained to the

greateſt degree of nicety, and that each obſerver's clock be exactly regulated to the equal time at his place: for without theſe particulars it would be impoſſible for the obſervers to reduce the times to thoſe which are reckoned under any given meridian; and without reducing the obſerved times of egreſs at different places to the time at ſome given place, the abſolute time that elapſeth between the egreſs at one place and at another could not be found. But the longitudes may be found, by obſerving the eclipſes of Jupiter's ſatellites; and a true meridian, for regulating the clock, to the time at any place, may be had, by obſerving when any given ſtar, within 20 or 30 degrees of the pole, is ſtationary, with regard to its azimuth, on the eaſt and weſt ſides of the pole; the pole itſelf being the middle point between theſe two ſtationary poſitions of the ſtar. And it is not material for the obſervers to know exactly either the true angular meaſure of the Sun's diameter, or of Venus's, in this caſe; for whatever their diameters be, it will make no ſenſible difference in the obſerved interval between the ſame contact, as ſeen from different places.

71. In the geometrical conſtruction of tranſits, the ſcale *AB* (Fig. 3. of Plate XVI.) may be divided into any given number of equal parts, anſwering to any aſſumed quantity of Venus's horizontal parallax from the Sun (which is always the difference between the horizontal parallax of Venus and that of the Sun), provided the whole length of the ſcale be equal to the ſemidiameter of the Earh's diſc in Fig. 4.—Thus, if we ſuppoſe Venus's horizontal parallax from the Sun to be only 26″ (inſtead of 31″), in which caſe the Sun's horizontal parallax muſt be 10″.3493, as in § 20, the reſt of the projection will anſwer to that ſcale: as *CD*, which contains only 26 equal parts, is the ſame length as *AB*, which contains 31. And by working in all other reſpects as taught from § 45 to

§ 62,

PL. XVII.

A MAP of the EARTH, *Upon which are marked the Hours and Minutes of true Times of the Entrance and Exit of* VENUS, *in its Passage over the* SUN's DISC, June 6th 1761. *The Times are computed to the Meridian of* LONDON, *and that which is expressed upon each dotted Line shews when the Transit begins or ends at all those Places which the same Line passes through. The beginning is between* II *and* III *in the Morning and the end between* VIII *and* IX. *The four black curve Lines shew at what Places the Transit begins, and at what Places its ends, both at Sun-rising and Sun-setting.*

§ 62, you will find the times of total ingreſs and beginning of egreſs; and conſequently, the duration of the tranſit at any given place, which muſt reſult from ſuch a parallax.

72. In projections of this kind, it may be eaſily conceived, that a right line paſſing continually through the center of Venus, and a given point of the Earth, and produced to the Sun's diſc, will mark the path of Venus on the Sun, as ſeen from the given point of the Earth: and in this there are three caſes. 1. When the given point is the Earth's center, at which there is no parallax, either in longitude or latitude. 2. When the given point is one of the poles, where there is no parallax of longitude; but a parallax of latitude, whoſe quantity is eaſily determined, by letting fall a perpendicular from the pole upon the plane of the ecliptic, and ſetting off the parallax of latitude on this perpendicular: and here, the polar tranſit-lines will be parallel to the central, as the poles have no motion ariſing from the Earth's diurnal rotation. 3. The laſt caſe is, when the given point of the Earth is any point of its ſurface, whoſe latitude is leſs than 90 degrees: then there is a parallax in latitude proportional to the perpendicular let fall upon the aboveſaid plane, from the given point; and a parallax in longitude proportional to the perpendicular let fall upon the axis of that plane, from the ſaid given point. And the effect of this laſt will be to alter the tranſit-line, both in poſition and length; and will prevent its being parallel to the central tranſit-line, unleſs when its axis and the axis of the Earth coincide, as ſeen from the Sun; which is a thing that may not happen in many ages.

ARTICLE VI.

Concerning the map of the transit. Plate XVII.

73. The title of this map, and the lines drawn upon it, together with the words annexed to these lines, and the numbers (hours and minutes) on the dotted lines, explain the whole of it so well, that no farther description seems requisite.

74. So far as I can examine the map by a good globe, the black curve lines are in general pretty well laid down, for shewing at what places the transit will begin, or end, at sun-rising or sun-setting, to all those places through which they are drawn, according to the times mentioned in the map. Only I question much whether the transit will begin at sun-rise to any place in *Africa*, that is west of the *Red Sea*; and am pretty certain that the Sun will not be risen to the northernmost part of *Madagascar* when the transit begins, as M. De L'Isle reckons the first contact of Venus with the Sun to be the beginning of the transit. So that the line which shews the entrance of Venus in the Sun's disc at sun-rising, seems to be a little too far west in the map, at all places which are south of *Asia Minor*: but in *Europe*, I think it is very well.

75. In delineating this map, I had M. De L'Isle's map of the transit before me. And the only difference between his map and this, is, 1. That in his map, the times are computed to the meridian of *Paris*; in this they are reduced to the meridian of *London*. 2. I have changed his meridional projection into that of the equatorial; by which, I apprehend, that the black curve lines, shewing at what places the transit begins, or ends, with the rising or setting Sun, appear more natural to the eye, and are more fully seen at once, than in the map from which I copied; for in that map the lines are interrupted and broke in the meridian

that

that divides the hemiſpheres; and the places where they ſhould join cannot be perceived ſo readily by thoſe who are not well ſkilled in the nature of ſtereographical projections.—The like may be ſaid of many of the dotted curve lines, on which are expreſſed the hours and minutes of the beginning or ending of the tranſit, which are the abſolute times at theſe places through which the lines are drawn, computed to the meridian of *London*.

ARTICLE VII.

Containing an Account of Mr. HORROX'*s Obſervation of the Tranſit of Venus over the Sun, in the Year* 1639; *as it is publiſhed in the* Annual Regiſter *for the Year* 1761.

76. When *Kepler* firſt conſtructed his (the Rudolphine) Tables upon the obſervations of *Tycho*, he ſoon became ſenſible that the Planets Mercury and Venus would ſometimes paſs over the Sun's diſc; and he predicted two tranſits of Venus, one for the year 1631, and the other for 1761, in a tract publiſhed at *Leipſick* in 1629, entitled, *Admonitio ad Aſtronomos, &c.* *Kepler* died ſome days before the tranſit in 1631, which he had predicted was to have happened. *Gaſſendi* looked for it at *Paris*, but in vain (ſee *Mercurius in Sole viſus, & Venus inviſa*). In effect, the imperfect ſtate of the Rudolphine Tables was the cauſe that the tranſit was expected in 1631, when none could be obſerved; and thoſe very tables did not give reaſon to expect one in 1639, when one was really obſerved.

When our illuſtrious countryman Mr. HORROX firſt applied himſelf to Aſtronomy, he computed Ephemerides for ſeveral years, from *Lanſbergius*'s Tables. After continuing his labours for ſome time, he was enabled to diſcover the imperfection of theſe tables; upon which he laid aſide his work, intending

intending to determine the positions of the stars from his own observations. But that the former part of his time spent in calculating from *Lansbergius* might not be thrown away, he made use of his Ephemerides to point out to him the situations of the planets. From hence he foresaw when their conjunctions, their appulses to the fixed stars, and the most remarkable phænomena in the heavens would happen; and prepared himself with the greatest care to observe them.

Hence he was encouraged to wait for the important observation of the transit of Venus in the year 1639; and no longer thought the former part of his time mis-spent, since his attention to *Lansbergius*'s Tables had enabled him to discover that the transit would certainly happen on the 24th of *November*. However, as these Tables had so often deceived him, he was unwilling to rely on them entirely, but consulted other Tables, and particularly those of *Kepler*; accordingly, in a letter to his friend *William Crabtree* of *Manchester*, dated *Hool*, *October* 26, 1639, he communicated his discovery to him, and earnestly desired him to make whatever observation he possibly could with his telescope, particularly to measure the diameter of the planet Venus; which, according to *Kepler*, would amount to 7 minutes of a degree, and according to *Lansbergius* to 11 minutes; but which, according to his own proportion, he expected it would hardly exceed one minute. He adds, that according to *Kepler*, the conjunction will be *November* 24, 1639, at 8 hours 1 minute A.M. at *Manchester*, and that the planet's latitude would be 14′ 10″ south; but according to his own corrections, he expected it to happen at 3 hours 57. min. P. M. at *Manchester*, with 10′ south latitude. But because a small alteration in *Kepler*'s numbers would greatly alter the time of conjunction, and the quantity of the planet's latitude, he advises to watch the whole day, and even on the preceding afternoon, and the morning of of the 25th, though he was entirely of opinion that the tranſit would happen on the 24th.

After having fully weighed and examined the ſeveral methods of obſerving this uncommon phæ-nomenon, he determined to tranſmit the Sun's image through a teleſcope into a dark chamber, rather than through a naked aperture, a method greatly commended by *Kepler*; for the Sun's image is not given ſufficiently large and diſtinct by the latter, unleſs at a very great diſtance from the aperture, which the narrowneſs of his ſituation would not allow of; nor would Venus's diameter be well defined, unleſs the aperture were very ſmall; whereas his teleſcope, which rendered the ſolar ſpots diſtinctly viſible, would ſhew him Venus's diameter well defined, and enable him to divide the Sun's limb more accurately.

He deſcribed a circle on paper which nearly equalled ſix inches, the narrowneſs of the place not allowing a larger ſize; but even this ſize admitted diviſions ſufficiently accurate. He divided the circumference into 360 degrees, and the diameter into 30 equal parts, each of which were ſubdivided into 4, and the whole therefore into 120. The ſubdiviſion might have ſtill been carried farther, but he truſted rather to the accuracy and niceneſs of his eye.

When the time of obſervation drew near, he adjuſted the apparatus, and cauſed the Sun's diſtinct image exactly to fill the circle on the paper; and though he could not expect the planet to enter upon the Sun's diſc before three o'clock in the afternoon of the 24th, from his own corrected numbers, upon which he chiefly relied; yet, becauſe the calculations in general from other tables gave the time of conjunction much ſooner, and ſome even on the 23d, he obſerved the Sun from the time of its riſing to nine o'clock; and again, a little before ten; at noon, and at one in the afternoon, being called in the intervals to buſineſs of the

the higheſt moment, which he could not neglect. But in all theſe times he ſaw nothing on the Sun's face, except one ſmall ſpot, which he had ſeen on the preceding day; and which alſo he afterward ſaw on ſome of the following days.

But at 3 hours 15 minutes in the afternoon, which was the firſt opportunity he had of repeating his obſervations, the clouds were entirely diſperſed and invited him to ſeize this favourable occaſion, which ſeemed to be providentially thrown in his way; for he then beheld the moſt agreeable ſight, a ſpot, which had been the object of his moſt ſanguine wiſhes, of an unuſual ſize, and of a perfectly circular ſhape, juſt wholly entered upon the Sun's diſc on the left ſide; ſo that the limbs of the Sun and Venus perfectly coincided in the very point of contact. He was immediately ſenſible that this ſpot was the planet Venus, and applied himſelf with the utmoſt care to proſecute his obſervations.

And, *Firſt*, with regard to the inclination, he found, by means of a diameter of the circle ſet perpendicular to the horizon, the plane of the circle being ſomewhat reclined on account of the Sun's altitude, that Venus had wholly entered upon the Sun's diſc, at 3 hours 15 minutes, at about 62°, 30′ (certainly between 60° and 65°) from the vertex toward the right hand. (Theſe were the appearances within the dark chamber, where the Sun's image and motion of the planet on it were both inverted and reverſed.) And this inclination continued conſtant, at leaſt to all ſenſe, till he had finiſhed the whole of his obſervation.

Secondly, The diſtances obſerved afterward between the centers of the Sun and Venus were as follows; At 3 hours 15 minutes by the clock, the diſtance was 14′ 24″; at 3 hours 35 minutes, the diſtance was 13′ 30″; at 3 hours 45 minutes, the diſtance was 13′ 0″. The apparent time of ſun-ſetting was at 3 hours 50 minutes—the true time

3 hours

3 hours 45 minutes—refraction keeping the Sun above the horizon for the space of 5 minutes.

Thirdly, He found Venus's diameter, by repeated observations, to exceed a thirtieth part of the Sun's diameter, by a sixth, or at most a fifth subdivision.—The diameter therefore of the Sun to that of Venus may be expressed, as 30 to 1.12. It certainly did not amount to 1. 30. nor yet to 1.20. And this was found, by observing Venus as well when near the Sun's limb, as when farther removed from it.

The place where this observation was made, was an obscure village called *Hool*, about 15 miles northward of *Liverpool*. The latitude of *Liverpool* had been often determined by *Horrox* to be 53° 20′; and therefore, that of *Hool* will be 53° 35′. The longitude of both seemed to him to be about 22° 30′ from the *Fortunate Islands*: that is 14° 15′ to the west of *Uraniburg*.

These were all the observations which the shortness of the time allowed him to make upon this most remarkable and uncommon sight; all that could be done, however, in so small a space of time, he very happily executed; and scarcely any thing farther remained for him to desire. In regard to the inclination alone, he could not obtain the utmost exactness; for it was extremely difficult, from the Sun's rapid motion, to observe it to any certainty within the degree. And he ingenuously confesses that he neither did, nor could possibly perform it. The rest are very much to be depended upon; and as exact as he could wish.

Mr. *Crabtree*, at *Manchester*, whom Mr. *Horrox* had desired to observe this transit, and who in mathematical knowledge was inferior to few, very readily complied with his friend's request; but the sky was very unfavourable to him, and he had only one sight of Venus on the Sun's disc, which was about 3 hours 35 minutes by the clock; the Sun then, for the first time, breaking out from the clouds;

clouds; at which time, he ſketched out Venus's ſituation upon paper, which *Horrox* found to coincide with his own obſervations.

Mr. *Horrox*, in his treatiſe on this ſubject, publiſhed by *Hevelius*, and from which almoſt the whole of this account has been collected, hopes for pardon from the aſtronomical world, for not making his intelligence more publick; but his diſcovery was made too late. He is deſirous however, in the ſpirit of a true philoſopher, that other aſtronomers were happy enough to obſerve it, who might either confirm or correct his obſervations. But ſuch confidence was repoſed in the tables at that time, that it does not appear that this tranſit of Venus was obſerved by any beſides our two ingenious countrymen, who proſecuted their aſtronomical ſtudies with ſuch eagerneſs and preciſion, that they muſt very ſoon have brought their favourite ſcience to a degree of perfection unknown at thoſe times. But unfortunately Mr. *Horrox* died on the 3d of *January* 1640-1, about the age of 25, juſt after he had put the laſt hand to his treatiſe, entitled *Venus in Sole viſa*, in which he ſhews himſelf to have had a more accurate knowledge of the dimenſions of the Solar Syſtem than his learned commentator *Hevelius*—*So far the Annual Regiſter.*

In the year 1691 *, Dr. HALLEY gave in a paper upon the tranſit of Venus (See *Lowthorpe*'s Abridgment of the Philoſophical Tranſactions, page 434.), in which he obſerves, from the tables then in uſe, that Venus returns to a conjunction with the Sun in her aſcending node in a period of 18 years, wanting 2 days 10 hours 52½ minutes; but that in the ſecond conjunction ſhe will have got 24′ 41″ farther to the ſouth than in the preceding. That after a period of 235 years 2 hours 10 minutes 9 ſeconds, ſhe returns to a conjunction more to the north by 11′ 33″; and after 243 years, wanting 43 minutes

* See the *Connoiſſance des Temps* for *A. D.* 1761.

minutes in a point more to the south by 13′ 8″. But if the second conjunction is in the year next after leap-year, it will be a day later.

The intervals of the conjunctions at the descending node are somewhat different. The second happens in a period of 8 years, wanting 2 days 6 hours 55 minutes, Venus being got more to the north by 19′ 58″. After 235 years 2 days 8 hours 18 minutes, she is 9′ 21″ more southerly: only, if the first year is a bissextile, a day must be added. And after 243 years 0 days 1 hour 23 minutes, the conjunction happens 10′ 37″ more to the north; and a day later, if the first year was bissextile. It is supposed, as in the old style, that all the centurial years are bissextiles.

Hence, Dr. HALLEY finds the years in which a transit may happen at the ascending node, in the month of *November* (old stile) to be these—918, 1161, 1396, 1631, 1639, 1874, 2109, 2117: and the transits in the month of *May* (old stile) at the descending node, to be in these years—1048, 1283, 1518, 1526, 1761, 1769, 1996, 2004.

In the first case, Dr. HALLEY makes the visible inclination of Venus's orbit to be 9° 5′, and her horary motion on the Sun 4′ 7″. In the latter, he finds her visible inclination to be 8′ 28″, and her horary motion 4′ 0″. In either case the greatest possible duration of a transit is 7 hours 56 minutes.

Dr. HALLEY could even then conclude, that if the interval in time between the two interior contacts of Venus with the Sun could be measured to the exactness of a second, in two places properly situated, the Sun's parallax might be determined within its 500dth part. But several years after, he explained this affair more fully, in a paper concerning the transit of Venus in the year 1761; which was published in the Philosophical Transactions, and of which the third of the preceding articles is a translation; the original having been wrote in *Latin* by the Doctor.

ARTICLE

ARTICLE VIII.

Containing a short account of some observations of the Transit of Venus, A. D. 1761, June 6*th*, *New Stile; and the distances of the Planets from the Sun, as deduced from those observations.*

Early in the morning, when every astronomer was prepared for observing the transit, it unluckily happened, that both at *London*, and the Royal Observatory at *Greenwich*, the sky was so overcast with clouds, as to render it doubtful whether any part of the transit should be seen:—and it was 38 minutes 21 seconds past 7 o'clock (apparent time) at *Greenwich*, when the Rev. Mr. *Bliss* our Astronomer Royal, first saw Venus on the Sun; at which instant, the center of Venus preceded the Sun's center by 6′ 18″.9 of right ascension, and was south of the Sun's center by 11′ 42″.1 of declination.— From that time to the beginning of egress the Doctor made several observations, both of the difference of right ascension and declination of the centers of the Sun and Venus; and at last found the beginning of egress, or instant of the internal contact of Venus with the Sun's limb, to be at 8 hours 19 minutes 0 seconds apparent time.—From the Doctor's own observations, and those which were made at *Shirburn* by another Gentleman, he has computed, that the mean time at *Greenwich* of the ecliptical conjunction of the Sun and Venus was at 51 minutes 20 seconds after 5 o'clock in the morning; that the place of the Sun and Venus was ♊ *(Gemini)* 15° 36′ 33″; and that the geocentric latitude of Venus was 9′ 44″.9 south.— her horary motion from the Sun 3′ 57″.13 retrograde;—and the angle then formed by the axis of the equator, and the axis of the ecliptic, was 6° 9′ 34″, decreasing hourly 1 minute of a degree.— By the means of three good observations, the diameter of Venus on the Sun was 58″.

Mr.

Mr. *Short* made his obſervations at *Savile-Houſe* in *London*, 30 ſeconds in time weſt from *Greenwich*, in preſence of his Royal Highneſs the Duke of *York*, accompanied by their Royal Highneſſes Prince *William*, Prince *Henry*, and Prince *Frederick*.—He firſt ſaw Venus on the Sun, through flying clouds, at 46 minutes 37 ſeconds after 5 o'clock; and at 6 hours 15 minutes 12 ſeconds he meaſured the diameter of Venus 59″.8.—He afterward found it to be 58″.9 when the ſky was more favourable.—And, through a reflecting teleſcope of two feet focus, magnifying 140 times, he found the internal contact of Venus with the Sun's limb to be at 8 hours 18 minutes 21½ ſeconds, apparent time; which, being reduced to the apparent time at *Greenwich*, was 8 hours 18 minutes 51½ ſeconds: ſo that his time of ſeeing the contact was 8½ ſeconds ſooner (in abſolute time) than the inſtant of its being ſeen at *Greenwich*.

Meſſrs. *Ellicott* and *Dolond* obſerved the internal contact at *Hackney*, and their time of ſeeing it, reduced to the time at *Greenwich*, was at 8 hours 18 minutes 36 ſeconds, which was 4 ſeconds ſooner in abſolute time than the contact was ſeen at *Greenwich*.

Mr. *Canton*, in *Spittle-ſquare*, *London*, 4′ 11″ weſt of *Greenwich* (equal to 16 ſeconds 44 thirds of time), meaſured the Sun's diameter 31′ 33″ 24‴, and the diameter of Venus on the Sun 58″; and by obſervation found the apparent time of the internal contact of Venus with the Sun's limb to be at 8 hours 18 minutes 41 ſeconds; which, by reduction, was only 2¼ ſeconds ſhort of the time at the Royal Obſervatory at *Greenwich*.

The Reverend Mr. *Richard Haydon*, at *Leſkeard*, in *Cornwall*, (16 minutes 10 ſeconds in time weſt from *London*, as ſtated by Dr. *Bevis*,) obſerved the internal contact to be at 8 hours 0 minutes 20 ſeconds, which by reduction was 8 hours 16 minutes 30 ſeconds at *Greenwich*: ſo that he muſt have ſeen

 it

it 2 minutes 30 ſeconds ſooner in abſolute time than it was ſeen at *Greenwich*—a difference by much too great to be occaſioned by the difference of parallaxes. But by a memorandum of Mr. *Haydon*'s ſome years before, it appears that he then ſuppoſed his weſt longitude to be near two minutes more; which brings his time to agree within half a minute of the time at *Greenwich*; to which the parallaxes will very nearly anſwer.

At *Stockholm* Obſervatory, latitude 59° 20½′ north, and longitude 1 hour 12 minutes eaſt from *Greenwich*, the whole of the tranſit was viſible; the total ingreſs was obſerved by Mr. *Wargentin* to be at 3 hours 39 minutes 23 ſeconds in the morning, and the beginning of egreſs at 9 hours 30 minutes 8 ſeconds; ſo that the whole duration between the two internal contacts, as ſeen at that place, was 5 hours 50 minutes 45 ſeconds.

At *Torneo* in *Lapland* (1 hour 27 minutes 28 ſeconds eaſt of *Paris*) Mr. *Hellant*, who is eſteemed a very good obſerver, found the total ingreſs to be at 4 hours 3 minutes 59 ſeconds; and the beginning of egreſs to be 9 hours 54 minutes 8 ſeconds. —So that the whole duration between the two internal contacts was 5 hours 50 minutes 9 ſeconds.

At *Hernoſand*, in *Sweden* (latitude 60° 38′ north, and longitude 1 hour 2 minutes 12 ſeconds eaſt of *Paris*), Mr. *Giſter* obſerved the total ingreſs to be at 3 hours 38 minutes 26 ſeconds; and the beginning of egreſs to be at 9 hours 29 minutes 21 ſeconds.—The duration between theſe two internal contacts 5 hours 50 minutes 56 ſeconds.

Mr. *De la Lande*, at *Paris*, obſerved the beginning of egreſs to be at 8 hours 28 minutes 26 ſeconds apparent time—But Mr. *Ferner* (who was then at *Conſtans*, 14½″ weſt of the Royal Obſervatory at *Paris*) obſerved the beginning of egreſs to be at 8 hours 28 minutes 29 ſeconds true time. The equation, or difference between the true and apparent

apparent time, was 1 minute 54 ſeconds.—The total ingreſs, being before the Sun roſe, could not be ſeen.

At *Tobolſk*, in *Siberia*, Mr. *Chappe* obſerved the total ingreſs to be at 7 hours 0 minutes 28 ſeconds in the morning, and the beginning of egreſs to be at 49 minutes $20\frac{1}{2}$ ſeconds after 12 at noon.—So that the whole duration of the tranſit between the internal contacts was 5 hours 48 minutes $52\frac{1}{2}$ ſeconds, as ſeen at that place; which was 2 minutes $3\frac{1}{2}$ ſeconds leſs than as ſeen at *Hernoſand* in *Sweden.*

At *Madraſs*, the Reverend Mr. *Hirſt* obſerved the total ingreſs to be at 7 hours 47 minutes 55 ſeconds apparent time in the morning; and the beginning of egreſs at 1 hour 39 minutes 38 ſeconds paſt noon.—The duration between theſe two internal contacts was 5 hours 51 minutes 43 ſeconds.

Profeſſor *Mathenci*, at *Bologna*, obſerved the beginning of egreſs to be at 9 hours 4 minutes 58 ſeconds.

At *Calcutta* (latitude 22° 30′ north, nearly 92° eaſt longitude from *London)* Mr. *William Magee* obſerved the total ingreſs to be at 8 hours 20 minutes 58 ſeconds in the morning, and the beginning of egreſs to be at 2 hours 11 minutes 34 ſeconds in the afternoon. The duration between the two internal contacts 5 hours 50 minutes 36 ſeconds.

At the *Cape of Good Hope* (1 hour 13 minutes 35 ſeconds eaſt from *Greenwich)* Mr. *Maſon* obſerved the beginning of egreſs to be at 9 hours 39 minutes 50 ſeconds in the morning.

All theſe times are collected from the obſerver's accounts, printed in the Philoſophical Tranſactions for the year 1762 and 1763, in which there are ſeveral other accounts that I have not tranſcribed.—The inſtants of Venus's total exit from the Sun are likewiſe mentioned; but they are here left out, as not of any uſe for finding the Sun's parallax.

Whoever compares theſe times of the internal contacts, as given in by different obſervers, will find ſuch difference among them, even thoſe which were taken upon the ſame ſpot, as will ſhew, that the inſtant of either contact could not be ſo accurately perceived by the obſervers as Dr. HALLEY thought it could; which probably ariſes from the difference of people's eyes, and the different magnifying powers of thoſe teleſcopes through which the contacts were ſeen.—If all the obſervers had made uſe of equal magnifying powers, there can be no doubt but that the times would have more nearly coincided; ſince it is plain, that ſuppoſing all their eyes to be equally quick and good, they whoſe teleſcopes magnified moſt, would perceive the point of internal contact ſooneſt, and of the total exit lateſt.

Mr. *Short* has taken an incredible deal of pains in deducing the quantity of the Sun's parallax, from the beſt of thoſe obſervations which were made both in *Britain* and abroad: and finds it to have been 8″.52 on the day of the tranſit, when the Sun was very nearly at his greateſt diſtance from the Earth; and conſequently 8″ 65 when the Sun is at his mean diſtance from the Earth.—And indeed, it would be very well worth every curious perſon's while, to purchaſe the ſecond part of Volume LII. of the Philoſophical Tranſactions, for the year 1763; even if it contained nothing more than Mr. *Short*'s paper on that ſubject.

The log. ſine (or tangent) of 8″.65 is 5.6219140, which being ſubtracted from the radius 10.0000000, leaves remaining the logarithm 4.3780860, whoſe number is 23882.84; which is the number of ſemidiameters of the Earth that the Sun is diſtant from it.—And this laſt number, 23882.84, being multiplied by 3985, the number of *Engliſh* miles contained in the Earth's ſemidiameter, gives 95,173,127 miles for the Earth's mean diſtance from the Sun.—But becauſe it is impoſſible, from the niceſt obſervations of the Sun's parallax, to be ſure of its true diſtance from the Earth within 100 miles, we ſhall at preſent, for the ſake of round numbers, ſtate the Earth's mean diſtance from the Sun at 95,173,000 *Engliſh* miles.

And then, from the numbers and analogies in § 11 and 14 of this Diſſertation, we find the mean diſtances of all the reſt of the planets from the Sun in miles to be as follows:—Mercury's diſtance, 36,841,468; Venus's diſtance, 68,891,486; Mars's diſtance, 145,014,148; Jupiter's diſtance, 494,990,976; and Saturn's diſtance, 907,956,130.

So that by comparing theſe diſtances with thoſe in the Tables at the end of the chapter on the Solar Syſtem *, it will be found that the dimenſions of the Syſtem are much greater than what was formerly imagined: and conſequently, that the Sun and all the planets (except the Earth) are much larger than as ſtated in that table.

The ſemidiameter of the Earth's annual orbit being equal to the Earth's mean diſtance from the Sun, viz. 95,173,000 miles, the whole diameter is 190,346,000 miles. And ſince the diameter of a circle is to its circumference as 1 to 3.14159 the circumference of the Earth's orbit is 597,989,090 miles.

And, as the Earth deſcribes this orbit in 365 days 6 hours (or in 8766 hours), it is plain that it travels at the rate of 68,217 miles every hour, and conſequently 11,369 miles every minute; ſo that its velocity in its orbit is at leaſt 142 times as great as the velocity of a cannon-ball, ſuppoſing the ball to move through 8 miles in a minute, which it is found to do very nearly:—and at this rate it would take 22 years 228 days for a cannon-ball to go from the Earth to the Sun.

On the 3d of *June*, in the year 1769, Venus will again paſs over the Sun's diſc, in ſuch a manner, as to afford a much eaſier and better method of inveſtigating the Sun's parallax than her tranſit

* Fronting page 42.

in the year 1761 has done.—But no part of *Britain* will be proper for obſerving that tranſit, ſo as to deduce any thing with reſpect to the Sun's parallax from it, becauſe it will begin but a little before ſun-ſet, and will be quite over before 2 o'clock next morning.—The apparent time of conjunction of the Sun and Venus, according to Dr. HALLEY's Tables, will be at 13 minutes paſt 10 o'clock at night at *London*; at which time the geocentric latitude of Venus will be full 10 minutes of a degree north from the Sun's center:—and therefore, as ſeen from the northern parts of the Earth, Venus will be conſiderably depreſſed by a parallax of latitude on the Sun's diſc; on which account, the viſible duration of the tranſit will be lengthened; and in the ſouthern parts of the Earth ſhe will be elevated by a parallax of latitude on the Sun, which will ſhorten the viſible duration of the tranſit, with reſpect to its duration as ſuppoſed to be ſeen from the Earth's center; to both which affections of duration the parallaxes of longitude will alſo conſpire.—So that every advantage which Dr. HALLEY expected from the late tranſit will be found in this, without the leaſt difficulty or embarraſſment.—It is therefore to be hoped, that neither coſt nor labour will be ſpared in duly obſerving this tranſit; eſpecially as there will not be ſuch another opportunity again in leſs than 105 years afterward.

The moſt proper places for obſerving the tranſit in the year 1769, is in the northern parts of *Lapland*, and the *Solomon Iſles* in the great *South-Sea*; at the former of which, the viſible duration between the two internal contacts will be at leaſt 22 minutes greater than at the latter, even though the Sun's parallax ſhould not be quite 9″.——If it be 9″. (which is the quantity I had aſſumed in a delineation of this tranſit, which I gave in to the

Royal

Royal Society before I had heard what Mr. *Short* had made it from the obſervations on the late tranſit), the difference of the viſible durations, as ſeen in *Lapland* and in the *Solomon Iſles*, will be as expreſſed in that delineation; and if the Sun's parallax be leſs than 9″ (as I now have very good reaſon to believe it is), the difference of durations will be leſs accordingly.

I N D E X.

The numeral Figures refer to the Articles, and the ſmall *n* to the Notes on the Articles.

A

Axis

D.

E.

H.

I.

J.

L.

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DIREC-

DIRECTIONS to the PLATES.

The ORRERY PLATE fronting the Title Page.

F I N I S.